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# RURAL STUDIES

## BOOK FOUR

RURAL STUDIES

BY

J. C. W. HOUGHTON, M.A.

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| BOOK I. | 154 pages. |
| BOOK II. | 192 pages. |
| BOOK III. | 192 pages. |
| BOOK IV. | 208 pages. |

# RURAL STUDIES

## BOOK FOUR

by

J. C. W. HOUGHTON,
M.A. (Cantab.)
Senior Lecturer at the City of Leeds Training College

Illustrated with drawings by
C. F. TUNNICLIFFE, A.R.A.
together with numerous sketches by the author,
and with photographs

*With thanks to those*
*who first found*
*'The Fields' and 'The Wood'*

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# PREFACE

This is the fourth book of a four-year course in rural studies.

Although the full course provides a good foundation for those pupils who wish to proceed further with their education in some branch of rural technology, the subject matter has been presented with a view to its educational rather than its instructional value—the method of observation and interpretation adopted aiming more particularly at a widening of interest and sharpening of inquiry.

Each book contains enough material for one lesson a week; furthermore many of the exercises are graded to provide practice in written expression, and have been designed for use in the English lesson. Should it be possible for the exercises to be done in one book, the work resulting from the pupil's own observations would constitute a simple but valuable environmental study.

From Mr. H. W. Marsh of J. M. Dent & Sons Ltd. I have had continual help in the preparation of the text and in the production of these books and I am very grateful for all he has so patiently done. I extend my thanks also to Mr. C. F. Tunnicliffe, who found time to favour me with so many delightful illustrations, and to the following who have provided photographs:

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Marsh Green
Elworth
Sandbach, Cheshire

J. C. W. Houghton.

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# I

# Farmland Fertility

For oute of olde feldys, as men sey,
  Comyth all this newe corne from yere to yere;
And oute of olde bokis, in good fey,
  Comyth all this new science that men lere.

CHAUCER (1340–1400).

A farmer should live as though he was going to die to-morrow,
But he should farm as though he were going to live for ever.

OLD COUNTRY SAYING.

IN THE central states of the U.S.A. lies a vast area of land, millions of acres in extent, that tells a story of misfortune and mismanagement. At one time green and fertile, these rolling plains were farmed by a thriving population of landworkers; but to-day the land lies derelict, the farmsteads are empty, and on the spreading acres not a blade of grass is to be found—nothing but a wasteland of dust as far as the eye can see. This American 'dust-bowl' as it is called came into being because the men who farmed the land knew nothing about soil and its fertility. For countless years before their coming, nature had 'farmed' the land successfully enough—producing year by year plentiful crops of prairie grass that was grazed by roving herds of buffalo. The soil was always 'in good heart' as we say and it was not until the farmers came along that this fertile land was laid to ruin. How was this disaster brought about?

Year after year these farmers grew crops of wheat which were sold off the land and nothing was returned to the soil—no manure of any kind: no straw, no dung, no chemical fertilizers. Under nature's management everything that the flourishing grasses took from the land was sooner or later returned to the soil from which it came—all the nitrates, all the phosphates, all the potash. Furthermore there was an annual increase of organic matter because the abundant natural vegetation was never removed: year by year the dying stems and leaves of the plants returned their substance to the soil in the form of humus: nothing was lost, nothing was carried away. But the robbery of plant foods—nitrogen, phosphorus, potash, and so on—that took place when the wheat crops were sold off the land year after year was bound to reduce the store of these

Plant foods that are sold off the farm in crops and stock need to be replaced. Here you see the farmer dressing his land with a mixture of phosphates and potash.

substances in the soil. Any good farmer knows that if he sells crops off his farm he must replenish the soil with plant foods and with humus. If he does not pay careful attention to this, his land will most certainly become poor and infertile. This does not happen all at once of course—it is possible to 'bleed' land for many years before disaster comes along; but sooner or later impoverishment of the soil does take place. Here is an old country saying that expresses this important fact very clearly:

> No man can take out of the land more than he puts in.

If he does, he will sooner or later find himself in the same sorry position as those American farmers who brought poverty both to themselves and to their soil.

## THE FOUR IMPORTANT MINERAL FOODS

Apart from the large quantities of water and carbon dioxide that the green plant needs in order to build up the substances of its body, there are many *mineral* substances in the soil that are necessary for plant growth. Some of these—iron and sulphur and magnesium, for example—are used in such tiny quantities that there is rarely a *deficiency* of them in any soil; but there are four mineral plant foods that are needed in greater quantities, and it is to the supply of these that farmers and gardeners need to give their careful attention.

They are:

1. Nitrates,
2. Phosphates,
3. Potash, and
4. Calcium.

*

Calcium is contained in lime and, as you know already, good farm soil is kept well supplied with lime for a variety of reasons so that there is usually an abundant supply of calcium in cultivated ground; but *nitrates*, *phosphates*, and *potash* are taken from the soil in fairly large quantities by most plants. The crops of an ordinary Norfolk four-course rotation, for example, would in four years remove about two hundredweights of phosphate and three hundredweights of potash *per acre*! The loss of nitrates is not so immediately serious as the loss of phosphates and potash, because as you learnt in Chapter 2 of Book III a well-cultivated soil contains myriads of bacteria that replenish the soil with nitrogen. Nevertheless a good deal of nitrogen is filched from the soil when crops or stock are sold off the farm and, like the phosphates and potash, it needs to be replaced by the farmer in order to keep his soil highly fertile.

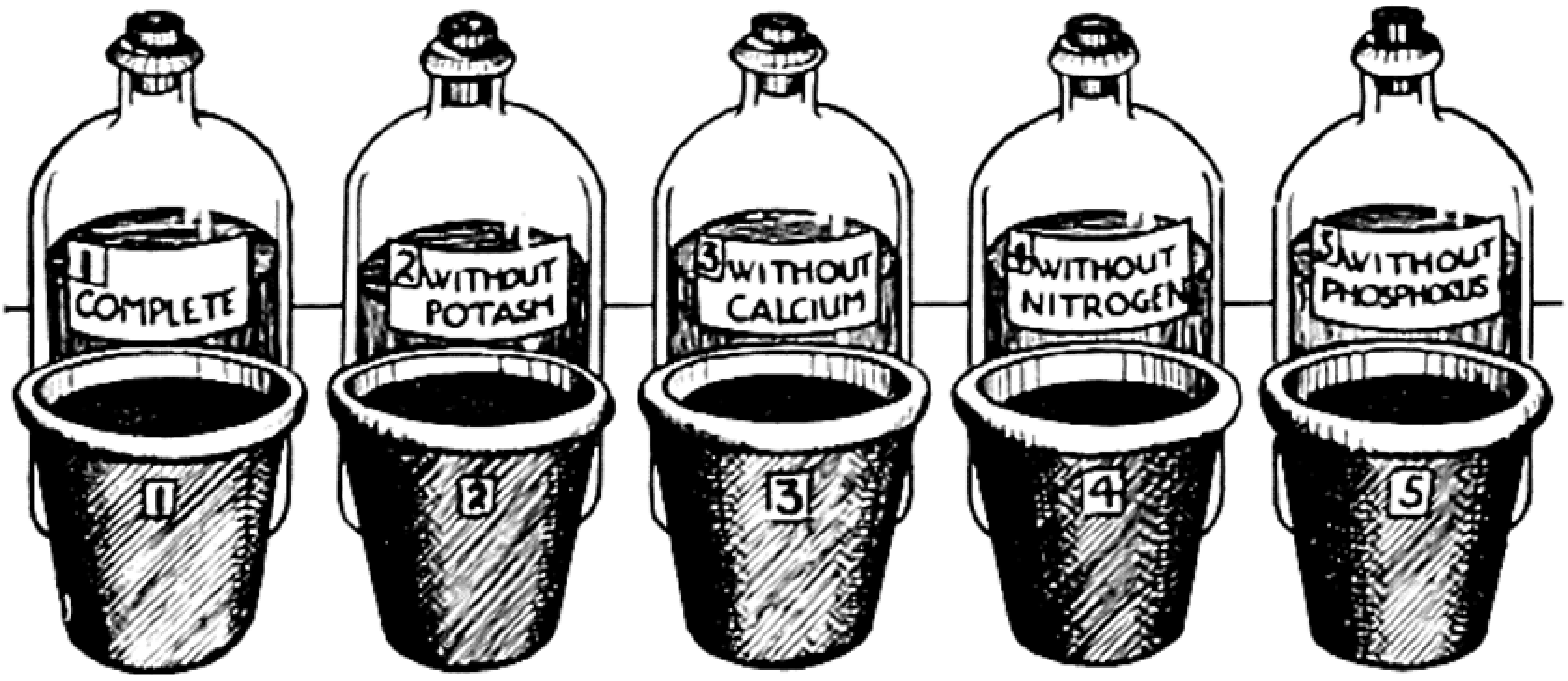
## AN EXPERIMENT WITH CHEMICAL FERTILIZERS

Let us set up an experiment to show the effects of a deficiency of potash, nitrogen, phosphates, and calcium on plant growth. If we see the effect of these deficiencies for ourselves, we shall more easily appreciate the importance of keeping the soil well supplied with them.

You will need:

(*a*) Five *clean* plant pots—5-inch or 8-inch pots will do quite well.

(*b*) Five bottles each of which will hold half a gallon. (Instead of half-gallon bottles you could use two-quart bottles for each of the solutions you



This experiment with plant foods needs very careful labelling, and you must take care always to dress the various pots with the same solutions.

are going to make: large cider bottles would do admirably. In any case you will need to make about half a gallon of each of the five solutions.)

(*c*) Enough *washed* silver sand to fill the pots within about one inch of the rim.

(*d*) An ounce of each of the following substances (the local chemist can supply these to order):

1. Potassium nitrate.
2. Magnesium sulphate.
3. Calcium sulphate.
4. Ferric phosphate (contains iron).
5. Potassium sulphate.
6. Sodium nitrate.
7. Ferric sulphate (contains iron).
8. Magnesium nitrate.

A solution of the first four of these substances will contain nitrogen, phosphorus, potash, and calcium—together with the necessary small quantities of iron, sulphur, and magnesium; and such a solution used as a liquid manure should supply all the needs of a healthy plant. In order to make the solution add 2 *grams* of potassium nitrate and ½ gram each of magnesium sulphate, calcium sulphate, and ferric phosphate to 1¾ quarts of either rain water or distilled water and shake the bottle until all the crystals are dissolved.[1] Before making the other solutions label the bottle carefully:

*Solution No. 1. Complete*

The second solution is made like No. 1 except that 2 grams of sodium nitrate are used instead of the potassium nitrate. This solution will contain no potash and it should be labelled:

*Solution No. 2. Without potash*

The third solution is also similar to No. 1 but ½ gram of magnesium nitrate is used instead of the calcium sulphate. This solution will contain no calcium and it should be labelled:

*Solution No. 3. Without calcium*

The fourth solution is made exactly like No. 1 except that 2 grams of potassium sulphate are used instead of the potassium nitrate. This solution will contain no nitrogen and should be labelled:

*Solution No. 4. Without nitrogen*

The fifth solution is made up again in a similar way to No. 1 except that ½ gram of ferric sulphate is used instead of the ferric phosphate. This solution will contain no phosphorus and it should be labelled:

*Solution No. 5. Without phosphorus*

When these solutions are ready you can prepare your pots to receive the plants by placing a crock and a handful of clean pebbles over each draining hole and then almost filling them with sand. The sand should come to within about an inch of the pot rim. There are many suitable plants for growing in such pots, but cuttings from greenhouse tradescantia (some people call it zebrina) root very freely and this plant is very easy to grow.[1] Select five shoots all of the same size—about three or four inches long—and after taking them from the 'parent' plant strip off the lower leaves and insert the shoots, one into each pot, to a depth of about two inches. Place the pots in a warm place near a window, put a saucer under each one so as to catch any solution that drains through, and label the pots to correspond with the solutions you have made.

---

[1] Do not be concerned by the milky appearance of the solution: this is as it should be.

Tradescantia (*Zebrina discolor*) is a good plant to use for testing the effect of culture solutions.

You need to keep the whole of the sand in the pots moistened with the appropriate solution. Once the sand is thoroughly damp a small quantity of solution should be added to it each day so as to maintain the moist condition. Take care not to waste the solution by adding more of it than is necessary. If you do add too much the excess will drain through into the saucers and you will have to pour it away. Your solutions should last for about five or six weeks, and at the end of that time you will need to make them up again so that the plants can go on growing for two months or so. By this time you will begin to see marked differences in the growth of the various plants according to the solutions with which you have been feeding them. Make a note in your Country Book of the length and number of stems on each plant, the healthy or sick appearance of each, together with the size and colour of the leaves.

---

[1] If you are unable to obtain any tradescantia moisten the sand in the pots and add a sunflower seed in each one. When these have germinated they will serve very well. Use rain water to keep the sand moist and begin using the solutions when the first proper leaves appear.

Your experiment will leave you in no doubt at all about the plant's need for nitrates, phosphates, potash, and calcium. The most healthy specimen will be in Pot No. 1 which was fed regularly with all four of these mineral substances; all the other plants will show some degree of inferiority. Notice carefully that a deficiency of *only one* of these substances prevents the plant from growing satisfactorily. The farmer or gardener needs to know which minerals are likely to be deficient in his soil. If, for example, there is a shortage of potash, it is no use feeding the crops, however liberally, with phosphatic manures or vice versa. A deficiency of one mineral cannot be made up by adding extra amounts of the others; most crop plants need all four in suitable quantities.

## IS HUMUS NECESSARY?

These various *inorganic* manures—nitrates, phosphates, potash, etc.—can be added to the soil in the form of chemical fertilizers: 'bag' manures the farmer calls them; and your experiment rather suggests that the humus which comes from *organic* manures—farmyard manure, ploughed-in crop remains, and so on—is not really necessary. But long experience has shown that humus is very necessary indeed: not only does it hold water so as to keep the soil moist during droughty periods, it also absorbs many of the mineral plant foods that the bag manures contain and this prevents them from being washed out of the soil—especially out of light sandy soils—in wet weather. And, of course, humus is in itself a source of mineral food for plants. The difficulty with regard to organic, humus-forming fertilizers is the difficulty of supply: there is not enough of them. No farmer ever has enough farmyard manure to dung all his fields each year, and no gardener ever has as much compost as he could use. That is one reason why the use of chemical fertilizers seems to be essential to our modern system of farming. And in any case, these chemical manures help the farmer to produce better crops even on those fields that have received liberal

Organic manure certainly supplies the soil with plant foods—but what other important effects does it have?

dressings of farmyard manure. Many field experiments showing that this is so have been carried out at the Agricultural Research Station at Rothamsted in Hertfordshire. The results of these experiments are very remarkable: mangolds, for example, were found to yield 4 tons to the acre with no fertilizers and no farmyard manure at all, 18 tons with farmyard manure only, 18 tons with chemical fertilizers only, but 27 tons per acre when the soil was supplied with both farmyard manure and fertilizers. The results with hay were even more remarkable: farmyard manure alone gave a yield of 28 cwt. to the acre, chemicals alone gave 22 cwt., and the two

The best crops of mangolds are grown on land that has received dressings both of farmyard manure and of chemical fertilizers also.

together gave a yield of 42 cwt.! These field 'trials' leave us in no doubt about the value of dressing soil with organic manures; but it is a combination of both organic and inorganic fertilizers that gives the best results.

## WHAT IS FERTILE SOIL?

In this chapter we are considering the 'profit and loss' account of soil as regards mineral plant foods, but we must not forget what has been learnt about soil fertility in earlier books. No soil can be fertile without an *adequate* supply of the essential plant minerals—nitrates, phosphates, and so on; but it is as well for us to remind ourselves at this stage that there are other conditions necessary for high fertility. You will remember that soil needs to be well drained so that air as well as rainfall can get to the plant roots; and it needs to contain suitable supplies of lime, not only in order to provide the plant food calcium, but also in order to promote a good crumb structure at the surface. Heavy clay soils, you will remember, form a good tilth when lime is present because the lime causes the clay to crumble. Furthermore both air, which is always present in well-drained soils, and lime are necessary for the well-being of those countless bacteria in the soil that help to turn the nitrogen of the air into nitrates[1] and those other bacteria that cause the dead remains of plants and animals to humify or rot down as we say.[2] During the 'rotting down' process or *humification* the nitrogenous plant foods that are 'locked' in the protein parts of the dead plants and animals are turned into chemical substances that living plants can use. Fertility, you

[1] Nitrogen-fixing bacteria.

[2] Nitrifying bacteria.

see, is made up of many factors, and the absence of any one of these factors renders the soil comparatively useless for the growing of crops. A soil that is completely water-logged, for example, can never be made fertile by the addition of farmyard manure or of fertilizers, lime, and so on. It needs to be drained as well. In the same way a field that is very acid will not grow good farm crops (except perhaps potatoes and oats which thrive in slightly acid land), no matter how well drained and manured it is. For a soil to be in really good heart *all* the fertility factors have to be attended to. Generally speaking the soil on British farms is adequately limed, well cultivated, and suitably drained; the most common cause of lack of fertility is the shortage of plant foods and of humus; and in considering the balance of farmland fertility we shall pay attention only to ways in which plant foods are used up and replaced.

The farmyard manure dressed into these ridges will *help* to produce a good crop of potatoes if the other soil fertility factors are attended to. What are these other factors?

### THE BALANCE OF FERTILITY ON A FARM

There are three ways in which the mineral richness of soil can be carried off the farm. It can be carried off in cash crops—bags of grain, loads of hay, and so on; it can be carried off by the milk van, for milk contains an appreciable amount of potash and phosphate; and it can be sold off in the form of animals—sheep, pigs, or cattle whose bodies are made largely of the food-stuffs grown on the farm fields. Cash sales of this sort are a constant drain on the mineral fertility of any farm, and whatever 'goes out through the gate' has to be brought in again in some form or other! Otherwise the fields will most certainly lose fertility and both farm and farmer will 'lose heart.'

What things can the farmer 'buy in' in order to maintain the balance of fertility? Years ago when rich animal food-stuffs were imported cheaply from abroad—high protein cattle cakes chiefly—most farmers bought them in large quantities and fed them very liberally to their beasts. These concentrated foods were very rich indeed in minerals. As you know no animal uses up all the food that it eats—considerable amounts are voided in the dung so that the animals that ate these concentrated foods produced a farmyard manure that had a very high mineral content indeed. Those farmers that kept large numbers of fattening bullocks were able to preserve the mineral fertility of their soils by this means alone. The bullocks that were fattened in enclosures or 'yards' near the farm buildings during the winter produced plenty of mineral-rich manure for spreading on the arable fields; and the bullocks that were fattened on the farm grassland during the summer, where the 'concentrates' were carried out to them each day, dropped their dung and urine on the fields they grazed. In this way, both cornland and pastureland were kept in good heart, and mineral deficiency was a condition rarely encountered.

Those fortunate days, however, were back in the middle years of the last century. Nowadays concentrated cattle foods are hard to come by; they are in very short supply, as you know. World populations have more than doubled since then, and the people overseas need these feeding stuffs for their own beasts. Furthermore Britain is not so rich a country as she was in those days. She has had to pay the price of two very costly wars (1914–18 and 1939–45); and because the people of other countries are now able to make for themselves many of the things we used to sell to them some of our biggest foreign markets have gone for ever; and we cannot now import so freely as in years gone by. Of course the smaller quantities of protein concentrate stock foods that the farmer is able to buy to-day do provide a certain mineral value in the dung and urine of his beasts—but the quantity is far less than it was in those earlier days and it has become essential for most farmers to use more chemical fertilizers in order to balance this loss.

### WHAT PLANT FOODS DOES FARMYARD MANURE CONTAIN?

Farmyard manure is produced when a mixture of litter (straw, bracken, etc.), dung, and urine is rotted down or humified by the action of nitrifying bacteria; but the manurial value of the manure depends to a great extent on the sort of stock that produces the dung and also on the way in which the farmer manages the manure-heap. Young stock of any kind are growing rapidly and they use up almost all the phosphates in their food in order to make their bones. The hard part of bones is made of calcium phosphate and the dung of young animals contains very little phosphate for this reason. The same is true of dairy cows in full milk; large quantities of nitrates, phosphates, and potash are used in the production of milk. The richest dung of all comes from fattening bullocks that are being fed with suitable amounts of protein concentrates. Their bones are fully formed, their bodies fully developed, and they do not produce milk; for these reasons they void much more nitrogen, phosphorus, and potash than either dairy cows or growing calves and their dung makes the richest manure of all.

Why does land that is grazed by young stock lose large quantities of phosphate?

Unfortunately much of the urine from dairy cattle that are 'kept up' during the winter is lost down the drain. This is really a very serious loss indeed because the urine contains almost all the potash and half of the nitrogen that the animal excretes. The dung itself contains most of the phosphates that the animal voids, a half of the nitrogen, and practically none of the potash. When the urine is allowed to go down the drain it gets into the sewers and is lost for ever. This is a very clear example of a mineral loss that will have to be replaced by costly chemical fertilizers because, of course, most of the potash and nitrogen that is lost in this way has come out of the soil on the farm—first into the plant and then into the cow and then down the drain. Some enterprising farmers construct underground storage tanks into which the urine can run from the cowsheds and the collected urine is sprayed on to their grassland. In this way they maintain the fertility balance of the grassland, so far as nitrogen and potash are concerned, without having to buy so much fertilizer as they otherwise would.

Another way in which plant foods are lost from farmyard manure is in drainage losses from the manure heap. Farmyard manure that is kept in the open for five or six months of the year gets frequent soakings with rain, and unless the manure is kept in a concrete pit this rain drains away and carries large quantities of valuable plant foods with it. When you reflect that over the years much of the farmland's mineral fertility passes through the manure heap you will easily understand that a badly kept dunghill can provide a serious fertility leak. Wise farmers know this very well and they take suitable steps to avoid the constant loss of urine and of dung 'liquor.' They realize that the money they spend in doing this will eventually be more than made up by better crops, better stock, and by the purchase of fewer bags of chemical fertilizer. While remembering the important *physical* effect that farmyard manure has on soil, because of the humus that it eventually becomes, it is very important to realize the tremendous amount of plant food that well-kept manure contains. It has been calculated that the farmyard manure used in Britain contains very much more plant food than the total quantity of chemical fertilizers used by British farmers—*the main source of soil fertility is still farmyard manure.* When you are told that over £5,000,000[1] are spent every year on 'bag' chemicals you will realize the tremendous value of the farmer's manure heaps.

## THE GREAT NEED FOR PHOSPHATES

Although nitrates, phosphates, and potash are all equally important to the plant, the greatest need on British fields is for phosphate. Why is this? We have already seen the ways in which mineral fertility can be lost from the farm and the need for replenishing the soil with all three substances is quite clear. But why do we need to apply even more phosphate than nitrate or potash? The answer is that farm stock retain in their bodies—chiefly in their skeletons—much more phosphorus than they retain of either nitrogen or potash. The loss of soil phosphates is the greatest loss of all. For this reason you will find that the amount of *phosphatic* fertilizer that the farmer applies to his fields is always greater than the amount of nitrates or of potash. Let us examine a typical dressing of inorganic manures. Three fertilizers the farmer may well use are superphosphate of lime, sulphate of ammonia (for nitrogen), and sulphate of potash. If he is dressing his land for a wheat crop he could use, per acre:

(*a*) 2 cwt. of supers,
(*b*) ½ cwt. of sulphate of ammonia,
(*c*) ½ cwt. of sulphate of potash.

There is no need for you to try to remember these figures, but you should remember the leading importance of phosphate—farm animals take from the soil far more phosphate than either nitrogen or potash.

---

[1] 1952.

There are various substances that can be used for the three important mineral foods you have been learning about. Thus, three of the many fertilizers that supply **nitrogen** are:

Nitrate of soda,
Sulphate of ammonia, and
Nitro chalk,

**phosphorus** is supplied by such things as
Superphosphate of lime,
Steamed bone flour, and
Basic slag;

and **potash** may be used in such forms as
Sulphate of potash,
Kainit, or
Muriate of potash.

## WHAT USE DOES THE PLANT MAKE OF NITROGEN, POTASH, AND PHOSPHORUS?

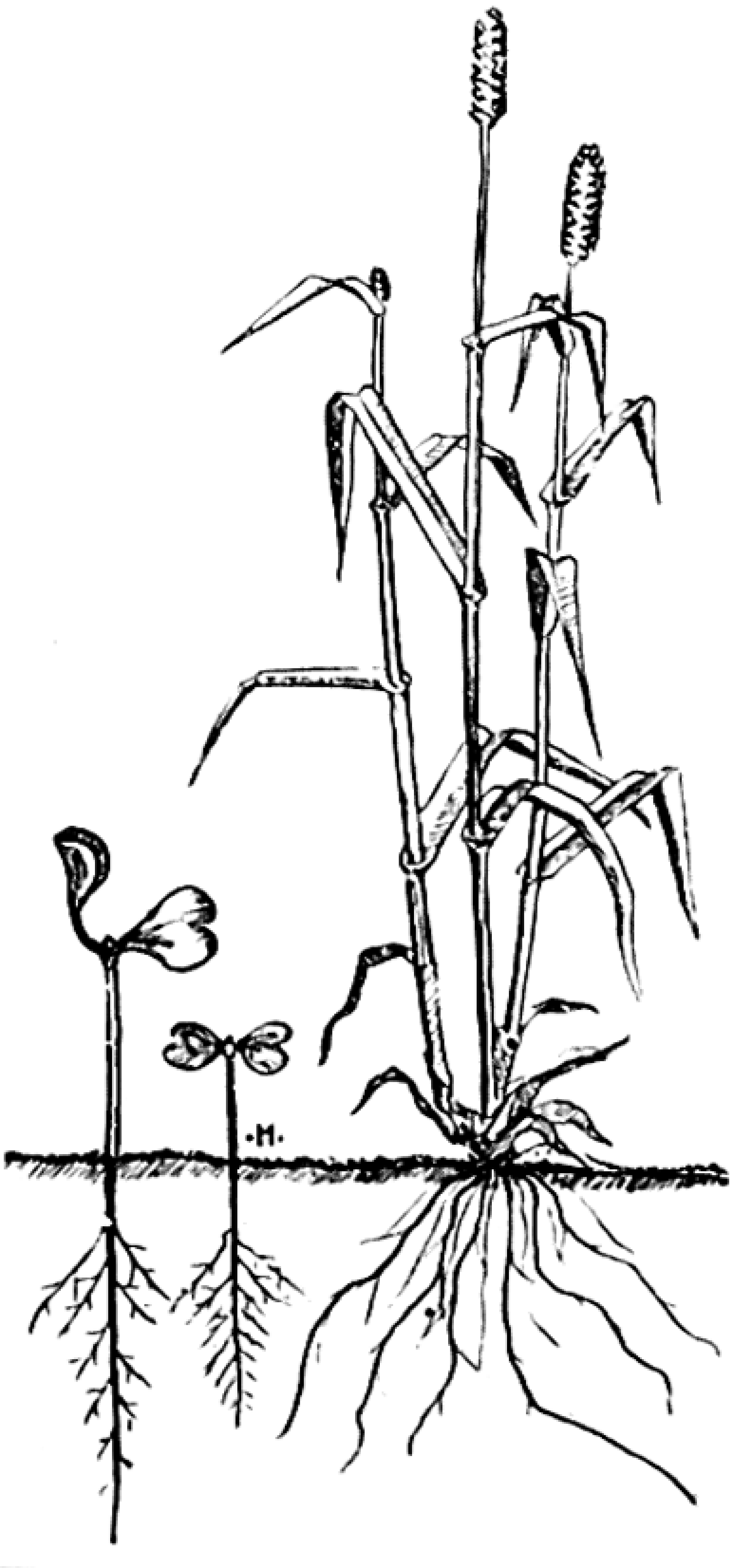
You have already learnt (Book III, Chapter 2) that the plant needs nitrates in order to make the protein of the new cells, and for this reason **nitrogenous foods cause the rapid formation of leaves and stems.** Nitrogen is obviously required in great quantities by leafy crops like kale, cabbage, mangolds, sugar-beet, and

Very leafy plants such as the cabbage need extra supplies of nitrogen.

so on. Most nitrogenous fertilizers are soluble in water, and if they were applied to the seed-bed in early spring—as phosphatic and potassic fertilizers often are—they might be washed out of the land by heavy rain and wasted; so that farmers do not usually dress the land with nitrogenous bag manures unless the nitrogen in them is likely to be used up quickly by the rapidly growing plant. Late spring is the time for this, and the farmer often gives his young wheat a 'top-dressing' in order to start it into quick growth; mangolds too are often top-dressed with nitrogen in April after they have been singled. In the garden you may find that the gardener gives his spring cabbages a 'fillip' by applying a top-dressing of nitrogen just as they begin to grow again when the days are getting warmer. But he takes care not to stimulate this fresh growth too soon; if he did the new young leaves might be damaged by late frosts.

There is, however, a limit to the amount of nitrogen that is valuable to crops. Plants that receive too much become over leafy and their maturity is delayed. Wheat, for example, is made later for harvest and the flowers of garden plants appear later and are less numerous if the plants on which they grow receive too much nitrogenous manure.

Phosphates, on the other hand, cannot be given to excess; their presence in soil tends to produce sturdy and healthy plants. **Phosphorus is especially important for young plants because it assists the development of roots.** If you wish to be sure that your garden seedlings will develop rapidly into strong young plants, take care to add some phosphatic manure to the soil. Furthermore flowering plants produce earlier blooms and earlier seed if they are well supplied with phosphorus, so that such crops as peas, beans, and wheat or other corn crops are ready for harvesting much earlier than they otherwise would be. Whereas nitrogen makes for rapid leaf growth but late maturity, phosphorus tends to produce a sturdy healthy plant that matures early. They are both necessary, you see, in different ways, and it is important that the soil should not be deficient in either of them. As your pot plants in the fertilizer experiment continue to grow, you should notice carefully the effect of leaving out phosphorus and leaving out nitrogen. You will find that neither of the two plants treated in these ways will grow satisfactorily; the one receiving nitrogen but no phosphorus will become very leafy but will lack sturdiness; and the one lacking nitrogen will fail to produce much new growth at all.


The root growth of seedlings and the seed formation of cereals are promoted by plenty of phosphatic food.

The potash fertilizers are, like the nitrates, very soluble in water, but they do not get washed out of the soil so easily, especially if there is much clay or humus present. Unlike the nitrogenous foods potash can be held by the clay and the humus of the soil, and for this reason potassic fertilizers can be safely applied to the land—along with the phosphates—when the seed-bed is being made. Only nitrogen, remember, needs to be top-dressed on to the growing crops. What effect does potash have on plant growth? **Potash helps photosynthesis to proceed at a rapid rate.** It is of course valuable to all plants for this reason, but those plants that manufacture large quantities of carbohydrates for storing in roots, tubers, and so on benefit very much from plentiful supplies of potash. This is especially true of potatoes and sugar-beet so that the farmer always provides these crops with extra amounts of potash foods. In addition potash acts as a sort of tonic to the plant, helping it to resist disease and to overcome the effects of too much nitrogen.

You will often hear farmers and gardeners talking about these three substances, and you now know some of the reasons why they are so important. You should learn these three facts by heart:

(1) Nitrogen promotes rapid leaf growth.

(2) Phosphorus promotes the formation of roots, shoots, flowers, and fruit.

(3) Potash speeds up photosynthesis and acts as a tonic to the plant.

Remember too that the maintenance of soil condition depends on the regular supply of humus and the regular replacement of the nitrogen, phosphorus, and potash that are carried off the farm in stock, crops, and milk, or that are lost in drainage water. There would never have been an American 'dust-bowl' if these matters had been attended to.

There is an old country saying which tells us that:

> No good farmer when he leaves a farm is ever sufficiently rewarded, and no bad farmer is ever sufficiently penalized.

If you remember this you will remember the importance of maintaining the fertility of soil.

## THINGS TO DO

(1) Write a composition entitled 'The Balance of Farm Fertility on a Farm I know.'

(2) Give concise answers to the following questions:

- (*a*) Of which three mineral plant foods is there a danger of deficiency in most farm soils?
- (*b*) Of which four mineral plant foods is there rarely a deficiency in farm soils?
- (*c*) What is humus?
- (*d*) What is the value of humus in the soil?
- (*e*) Name four factors that make a soil fertile.
- (*f*) What is the most common cause of infertility in British soils?
- (*g*) What class of cattle produce the richest farmyard manure?
- (*h*) What important plant foods do animals void in their urine?
- (*i*) Why do farmers use soluble nitrogenous fertilizers only as a top-dressing?
- (*j*) What is the effect of nitrogen on plant growth?
- (*k*) What would have prevented the American 'dust-bowl'?

(3) Visit a farm in your locality and ask the farmer if he will let you have small samples of at least two nitrogenous fertilizers, two phosphatic fertilizers, and two potassic fertilizers. Write the names of these substances in your Country Book and beneath the name of each fertilizer write a short description of its appearance.

(4) Select three fields on your local farm (including one field of ley pasture) and ask the farmer:

(*a*) What manuring these fields had for the crop they have carried this year, and

(*b*) What manures he intends to give them for the crop next year.

Write out what he tells you in your Country Book—taking care to name the crops in each field—and explain the reason that led him to decide on his plan of manuring.

(5) Ask your farmer friend to tell you, if he will, what he sold off his farm last year and what he bought in. Make a list of these under two headings:

| SOLD OFF | BOUGHT IN |
|---|---|

Do you think these two columns likely to balance one another as regards fertility? Explain your answer.

## AN INTERESTING DEBATE

There are numerous people who say that the use of inorganic fertilizers is a grave error; they believe that the bumper crops produced by this means have a harmful effect on the people and the farm animals that consume them. There is no direct *proof* that this is so, and it may be quite untrue. But it is worth thinking about; and it would make an excellent and important subject for a school debate. You can get all the facts and opinions against the use of chemical manures from: The Secretary, The Soil Association, New Bells Farm, Haughley, Suffolk.

## 2

# The Forests of Britain

Are not these woods
More free from peril than the envious court?

*As You Like It* (SHAKESPEARE).

O Man, when wilt thou come fit comrade of such trees, fair mate and crown of such a scene?

EDWARD CARPENTER.

IN THE early days of her history, Britain was covered with vast areas of forest land; trees such as birch, oak, ash, beech, and Scots pine grew in great profusion in various parts of the country, not only because of the suitable climate, but also because most British soils are ideal for the establishment of forests. As the years went by, however, and as the population grew, most of these forests were removed. Timber was always in great demand for the building of houses or ships; and the gradual spread of agriculture made it necessary to fell millions of acres of woodland so as to increase the area of arable land for the production of food. Our total area of productive forest land to-day [1] covers only a little over 2,000,000 acres—scarcely more than 3 per cent of the area of our islands.

Compared with farm crops, timber is a very slow growing product of the land indeed, and the re-establishment of felled woodlands takes long periods of time. Even in the Middle Ages the rapid disappearance of our trees gave considerable concern to thinking people; but it is only in more recent times that any serious attempt has been made to remedy the situation—and not until the end of the 1914–18 war was anything definite done. The serious shortage of home-grown timber during that desperate war gave the Government of Great Britain a rude shock. We had been relying for our timber supplies on importations from foreign countries—Norway, Sweden, North America, and so on—but the submarine *blockade* during the First World War reduced our importations so much that the Government had to seek home-grown supplies. These supplies were not, however, to be had in sufficient quantities, and for the first time in history our deplorable shortage of growing timber was fully realized. The result was that a body of men called *The Forestry Commission* was set up in 1919. They were required by the Government to draw up a programme of forest planting so as to ensure good supplies of home-produced timber for future generations. During the past thirty-four years[1] their work has been going

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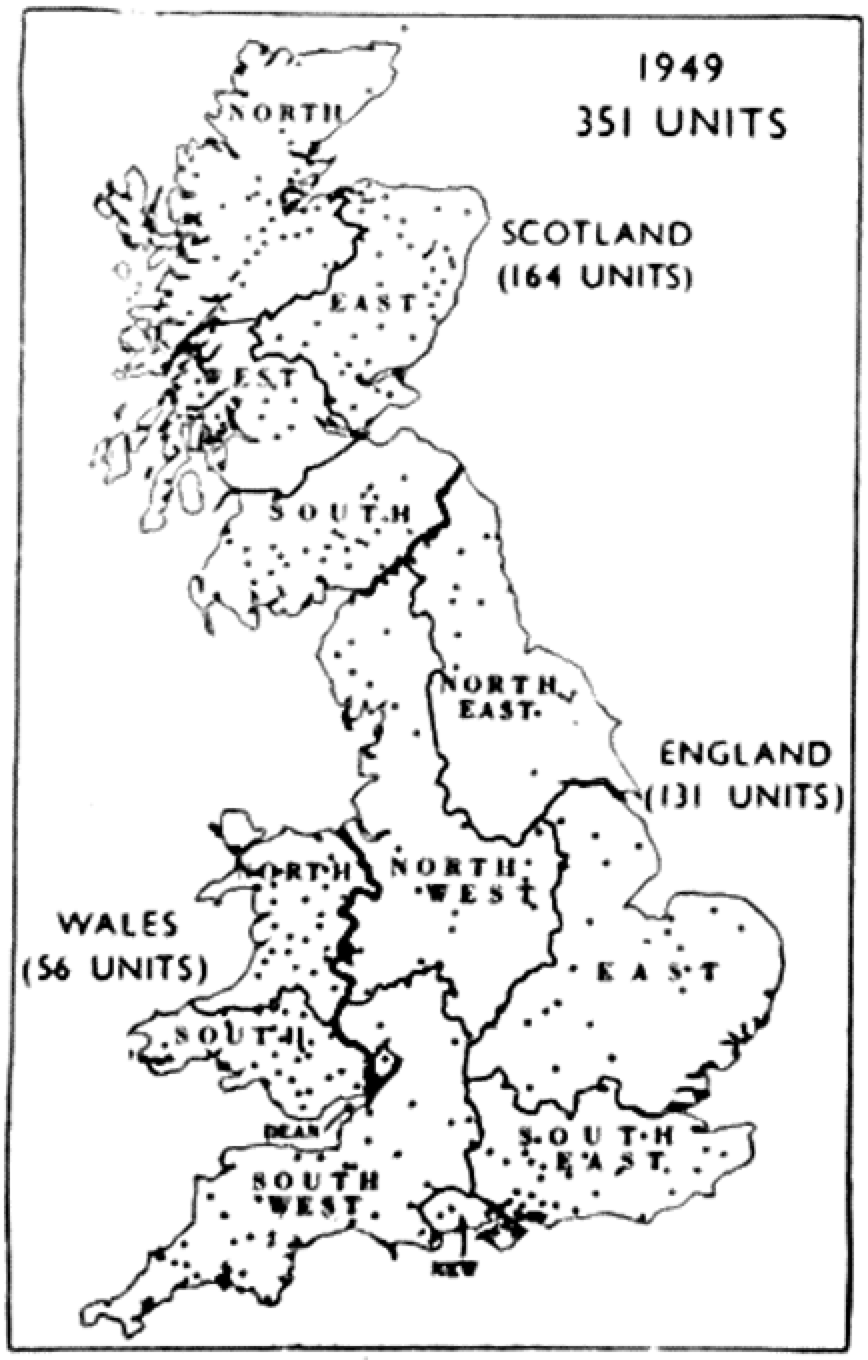
[1] A census was completed in 1949.



This map shows you that new forests are beginning to appear throughout Great Britain. Who will reap most benefit from all this work?

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[1] 1919–53.

steadily forward and they have provided us with about half a million acres of new plantations. If you find it difficult to visualize so great an area you should remind yourself that it is about equal to the whole of Cheshire or Norfolk, Wiltshire or Staffordshire, Cumberland or Hampshire, or of Gloucestershire. If you do not happen to live in any one of these counties, have a look at your atlas and you will then realize what a tremendous improvement has been made. For the first time in her history, Great Britain is making real progress with the important work of *afforestation*. An examination of the forest map of 1949 will show you where

This extensive plantation of Sitka spruce at Kerry in Montgomeryshire was planted twenty-five years ago by the Forestry Commission.

much of this planting has been done. As you will see, all parts of Britain are receiving attention; and most of the 351 forest 'units' owned by the Forestry Commission have already been partially planted up.

### THE FOREST WORKER

Over 12,000 trained men are regularly at work in our woodlands where they live a strenuous, interesting, and healthy life. Forest work is a new trade in Britain and many of these men have had to be specially trained and instructed. It was necessary to build a considerable number of timber houses near to the forests themselves for these workers and their families; and small groups of dwellings were put up in many places. For the larger forests, more extensive building has become necessary and large numbers of special forest villages are at present being planned. Near to the Forest of Kielder in Northumberland, for example, there are to be eight such villages and one of these is already (1953) under construction. Each village is to have its own church, shops, public hall, school, recreation grounds, and so on, together with enough houses for about seven hundred people. In this way numerous forestry communities will come into being. Life in these remote villages will be far different from existence in a town or city of course; but to be one of a small group of people all interested in the same kind of occupation, and all having one main object in view—i.e. the success of the forest for which they are responsible—is surely one of the happiest ways of living. And it is something so entirely new in Britain. In other countries—in North America, in Central Europe, and in Scandinavia—forestry and lumbering are ancient skills; but for over a thousand years we in Great Britain have been destroying our forests; and the forester's craft and way of life have been unknown to us. At last, however, the tide has turned and forestry work has become work of paramount importance. It is probable that these forest villages will be inhabited by some of the happiest, healthiest, and most hard-working people in Britain.

These men are giving a final thinning to a maturing larch wood. How do they decide which trees to fell?

SOME WOODLAND SKILLS

The work is very varied indeed, but the man of the forest, like his *counterpart* on the farm, has to be able to turn his hand to all sorts of jobs. Timber is a crop, and like most other crops it has to be carefully tended during its growth and harvested in the most suitable way. *Most of our forest trees are raised from seed*; and although considerable quantities of the seed are imported, large quantities of home-produced seed are also used. Indeed the gathering of suitable tree seeds is one of the tasks the forest worker may be called upon to do.

The seeds are sown in specially prepared seed-beds, and the young plants have to be protected, like the seedlings of any other crop, from the attacks of birds, insects, or rodents, from the ravages of severe weather, and from the encroachment of weeds. After one—or maybe two—years in the seed-bed the young plants are moved to a nursery bed where they are spaced in long rows called *nursery lines* so that they can grow sturdy roots. If you plant cabbages in the garden you usually put them into very good soil and take individual care of them; but forest-tree transplants cannot receive the same amount of attention when they go out into the plantations because there are so many of them to deal with; and the soil into which they go is usually of the poorest kind. For this reason they need to be kept in the nursery lines and to be carefully tended while they are there in order to develop a good root system. This ensures a good 'take' when they go finally to their permanent quarters in the plantation. When the final planting is done, the young trees are placed only a few feet apart so that in about twelve or fifteen years' time, when the *thicket* stage is reached, they will force one another into rapid upward growth; in this way none but long, straight trunks are formed—which is exactly what is wanted, because straight trunks with no side branches provide timber that is straight-grained and easy to work.

If these tightly packed trees were allowed to go on growing without attention many of them would be killed by their neighbours and many would become tall, weak, and spindly. In order to prevent this the trees are *thinned* from time to time, the thinnings being trimmed and cut into pit props. The age at which the first thinning takes place depends, of course, on the rate at which the young trees have grown; generally, however, it commences when the plantation is about twenty years old and continues at intervals until the forest is fully established. The later thinnings are big enough to be used for other purposes besides pit props; indeed they provide substantial trunks that can be taken to the saw-mill for cutting into planks.

The fellings from this plantation served one purpose while they were growing; and they will be put to further use now they are cut. Can you explain this twofold function?

### WHAT KIND OF TREES ARE PLANTED?

With the exception of the Scots pine, all our big native trees, in times gone by, were hardwoods—the oak, beech, ash, birch, and so on. The plantations of the Forestry Commission are, however, made up almost entirely of coniferous trees like the spruce, pine, larch, and Douglas fir. Indeed these 'softwoods'—all of which, except the Scots pine, are foreign trees—make up 94 per cent of the new plantations. There is no doubt that the continued planting of large expanses of conifers will eventually change the appearance of Britain and there are several reasons for this.

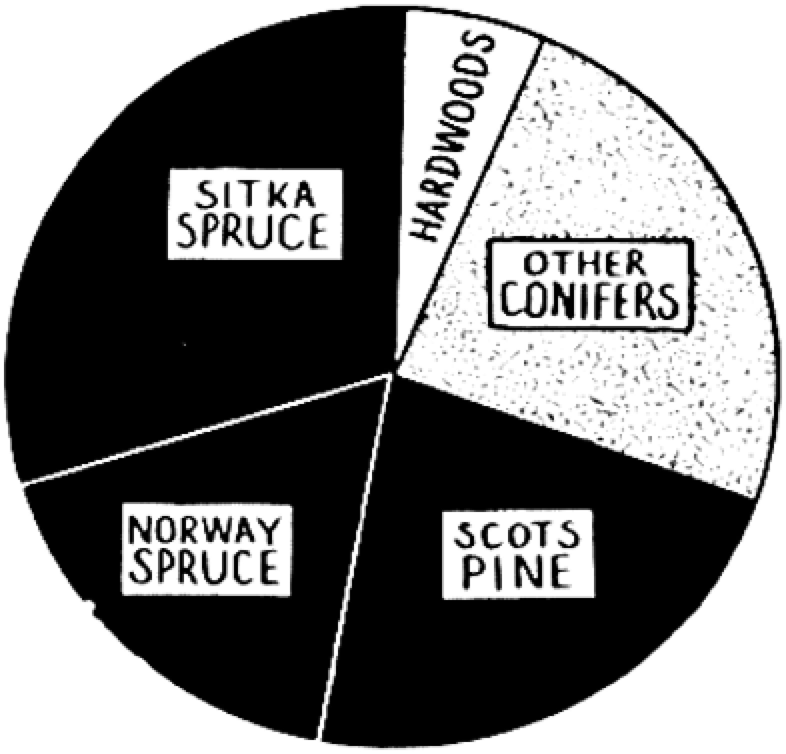
First of all, mature conifers have a very different appearance from mature hardwood trees such as the beech or the oak. Conifers and hardwood trees are both exceedingly beautiful, but they are beautiful in different ways. There is a great deal of difference between the attractive grace of a mature spruce-tree, for instance, and the rugged lines of a fully grown oak. Furthermore the deciduous trees lose their leaves in winter and the patterns made by their great limbs and the tracery of their innumerable twigs are a source of great pleasure; the winter landscape of Britain is made lovely by such things. Most of the conifers, however, retain their leaves throughout the year and they do not provide this change of scene in the winter. Nor is the floor of an evergreen woodland so attractively arrayed with the smaller plants and flowers. A mature wood of broad-leaved trees *in open canopy* allows a great deal more light to reach the ground than is possible in coniferous woodland and the ground *flora* in a broad-leaved forest is correspondingly more abundant. We are sometimes tempted to complain of the monotonous appearance of the serried rows of trees in our new forests but this is a rather thoughtless criticism. We must remember that the principal purpose of afforestation is timber production; and whether we plant softwoods or hardwoods this close and regular planting would be essential for the production of straight timber—it is the very basis of good forestry. In any case the uniform appearance of any type of forest disappears when the thinnings have been taken out and the woodland is mature. But there is no doubt that the future appearance of Britain would be more varied and more attractive if we could have a larger proportion of hardwood trees. It is obvious, however, that the Forestry Commission must be aware of these things so let us see why they choose to plant such a large proportion of softwoods. What are the problems that face them?

In the first place most of the conifers produce timber very rapidly—much more rapidly than hardwood trees. They grow faster—especially in the exposed places where much of the planting has to be done—and as we are continuously short of timber this is a very important difference. And because the softwood timbers are more rapidly produced, they are cheaper; and the market demand for them is consequently greater than it is for hardwoods. Years ago, before timber importation took place on a big scale, our abundant native hardwoods were commonly used; but with the reduced supplies and increasing costs of hardwood timber, the fashion has changed and the demand for hardwoods has diminished. Furthermore there are many upland areas in the north and north-west of Britain and many smoky areas near to industrial towns that are quite unsuitable for the establishment of hardwood forests. There would be very little timber production at all in such regions if the softwoods—including the native Scots pine—were not planted. Considerations of this nature have very naturally led to the strong emphasis on the planting of coniferous woodland, especially in these early years of our forestry programme. When our total areas of plantation are very much greater than they are at present it will probably prove possible—certainly it would be desirable—to plant up a greater acreage of deciduous woodland, particularly in the sheltered valleys and in those parts of the Midlands and southern England where the deciduous trees flourish so well. The Forestry Commission are aware of the possibilities, and as time goes on they will probably be able to give more consideration to this important question than they can at present. In the meantime you yourself can do much valuable work by planting the wild seedlings of hardwood trees in hedgerows and other places where they will have a chance to grow.

## WHICH ARE THE MOST POPULAR CONIFEROUS TREES FOR MODERN PLANTING?

The great majority of the coniferous trees that are planted are made up of one native and six foreign species. They are the native Scots pine, the Corsican pine, the Norway spruce, the Sitka spruce, the European larch, the Japanese larch, and the Douglas fir; and of these, the two spruces and the Scots pine are by far the most popular. *Sitka spruce, Norway spruce, and*

*Scots pine occupy almost 70 per cent of the area of our new plantations.* What are the reasons for the overwhelming popularity of these three trees?



This diagram gives a clear idea of the relative amounts of different timbers in British forests. Try to *estimate* the percentages of the various species planted.

As you already know, the various farm crops thrive best in the particular soils and climates that are most suitable to them. In exactly the same way the trees that the forester plants have to be chosen according to the soils and climates that he has at his disposal. The best soils and the areas of mildest climate are already in use for agricultural purposes, and the forester has to be content with upland acres and with poor soils. It has been found that the two spruces and the Scots pine are the three trees best adapted to the climate and the soils of those storm-swept hills and exposed mountainous slopes where most of the Forestry Commission's planting has to be done. There are over 200,000 acres of spruce—Norwegian and Sitka[1]—in the new plantations, and the Scots pine occupies about 100,000 acres. You may wonder why Scots pine, being a native tree, is not planted even more widely than the two foreign spruces; but in regions of heavy snowfall the rugged branches and the long needles of the Scots pine catch and hold tremendous weights of snow. This quite frequently leads to *snow-break*: the branches of the tree are torn away by the burden of snow and the whole tree may well be ruined. The downward sweeping branches and the short needles of the spruces on the other hand allow heavy falls of snow to slip smoothly to the ground so that in severe wintry weather the spruces suffer much less damage from snow than the Scots pine does. However, Scots pine is often planted together with spruce because the tender young spruce-trees usually grow better when they are protected from strong winds and frost by a shelter belt of Scots pine.

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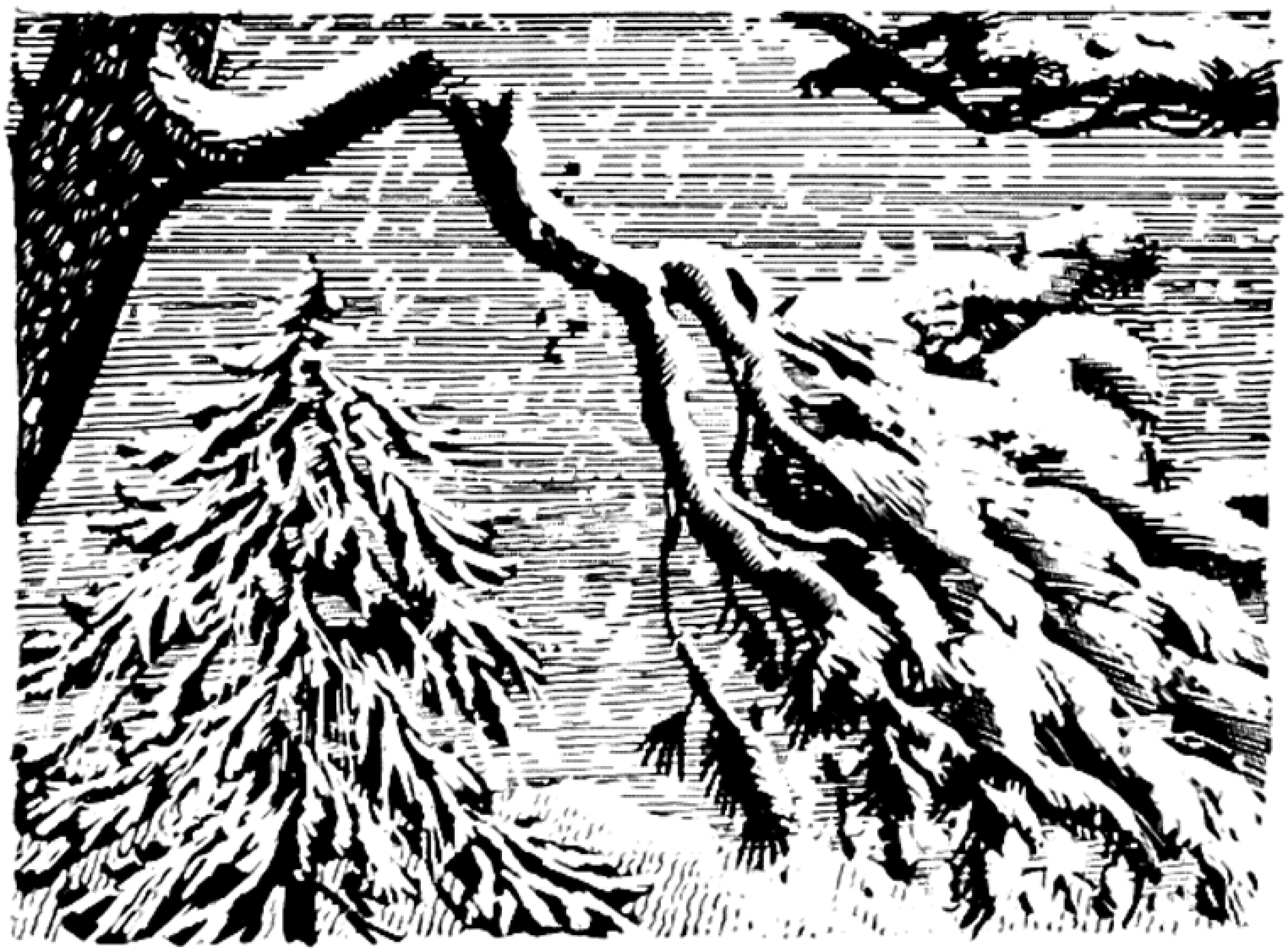
[1] You learnt in *Rural Studies*, Book II, how to recognize the Norway spruce, and you will hear more about the Sitka spruce later in this chapter.



A heavy fall of snow has fractured the limbs of this Scots pine; but, as you see, the spruce remains undamaged. Can you give the reason?

Spruce timber, you will remember,[1] is not very suitable for outdoor use because it is not very durable, whereas larch provides a most valuable wood; and it is unfortunate that we have been able to plant larch to the extent of only 12 per cent or so in our new plantations. But the larch really is not a very suitable tree for British forestry. Even in the best forestry soils, larch rarely shows its true magnificence as a tree in Britain. This is because in the natural homes of the larches—in the Himalayas, in the Alps, and in the Arctic latitudes of Europe—the summer sunshine is either very much stronger or very much more prolonged than it is here in Britain. In the Alps and the Himalayas the summer sunlight is intense; and in far northern latitudes—in northern Siberia, for example—there is no sunset at all for three or four months of the year. The summer sunlight of Arctic regions is continuous! These unusual conditions are not to be found in Britain and it is little wonder that the larches, when deprived of the strong sunlight in which they so much revel, do not flourish with us. It is not our winters that trouble them—they are used to prolonged and severe winters in their *native habitat*—it is the lack of sunshine.

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[1] *Rural Studies,* Book II, page 177.

What of the other two foreign coniferous trees—Douglas fir and Corsican pine—that are planted in some places but not so commonly? Douglas fir would be much more in favour than it is if it could be more easily established in its early stages. It is, as you know, the fastest growing tree of all and it reaches a tremendous height—300 feet or more—in its native home on the western seaboard of North America. It has in former years been widely planted in Britain and we already have over 20,000 acres of Douglas fir in our woodlands; but we should undoubtedly have more of it if it did not need so much attention in the early years of its life: young Douglas fir is not 'wind-firm' on soft land and it has been found necessary on occasion to go to the trouble and expense of staking individual trees—an enormous and costly job in a big plantation. Corsican pine, however, is of increasing importance in certain areas, particularly in plantations near to smoky cities where it seems to thrive. About 7 per cent of our new woodland acres—i.e. about 31,000 acres—consist of Corsican pine: and most of these 31,000 acres are situated in smoky areas in central and southern Britain.

The picture shows the lower half of the tallest tree in Europe—a Douglas fir in the grounds of Powys Castle, Montgomeryshire.

## THE SCOTS PINE

Mature Scots pines are to be seen in many parts of Britain, so that we can easily see the tree in its full beauty. Unlike many conifers this species is rounded at the top, not pointed. In young plantations the vigorous leading shoot does give to the tree a conical appearance; but once the main shaft of the trunk has been established, several lateral branches develop at the top and the handsome crown assumes its typical broad and graceful shape. At maturity the Scots pine may reach a height of a hundred feet or more and the base of the trunk is often three or four feet across. This trunk is easy to recognize. The outer bark is very deeply *fissured* and it is made up of many loose and irregular 'plates' that overlap one another to form a most attractive pattern.[1] One of the most striking features of the tree is the colour of its upper branches. In the light of a setting sun they have a distinctive orange or dull red appearance, and this ruddy tinge, in combination with the typical dark, blue-green leaves of the Scots pine, presents a very striking and beautiful picture. No other tree is quite so colourful at all times of the year. The leaves are long and needle-like and you will see that they are in pairs. Each pair is fixed into a short sheath which is rather like a small rubber band. Have a look also at the buds—they are blunt and resinous.

The seeds of all softwood trees are produced in cones and you are no doubt familiar with the cones of numerous different trees. The illustration (p. 43) shows clearly what the cone of the Scots pine looks like: it is quite hard and is covered with a regular pattern of angular knobs. Some cones are scaly and quite springy to the touch but the cone of Scots pine is firm and woody. These cones correspond to the fruits of hardwood trees and they are developed, as you might expect, from the female flowers which, together with the male flowers, appear in May or June. The brownish female flowers grow singly or in pairs at the tips of the shoots, and after fertilization each female flower develops into a dark green fleshy cone which remains green for a whole year. At the end of that time it turns brown, but it is not until the second spring—two years after fertilization has taken place—that the cone opens and allows the seeds to fall. You may have wondered why some of the Scots pine cones you have picked up were tightly closed while others were loose and open. It depends on whether or not the cone is mature. The seeds are winged, and when released they spin on the breeze in much the same way as the winged fruits of the sycamore.

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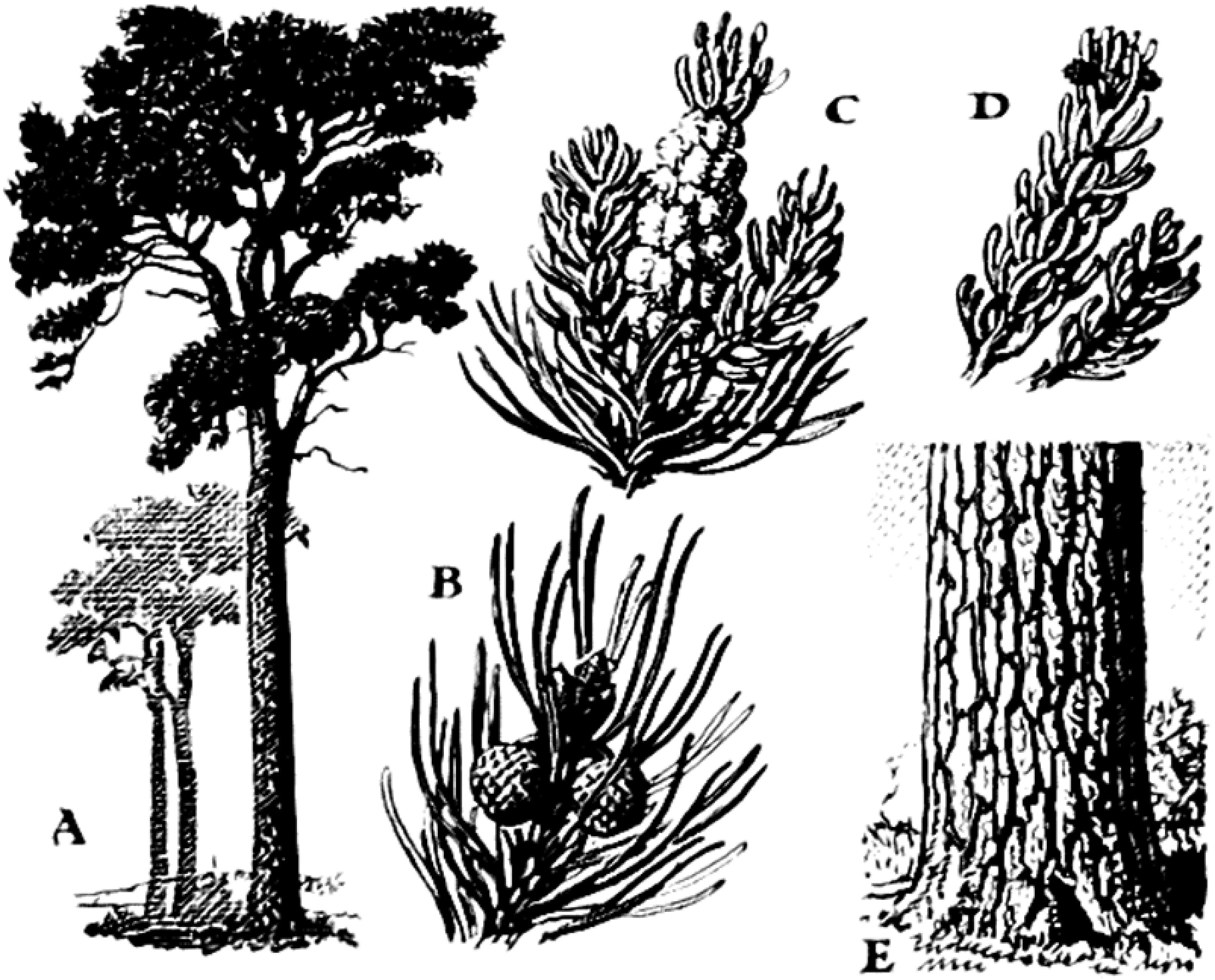
[1] What broad-leaved tree has a scaly trunk of this nature?

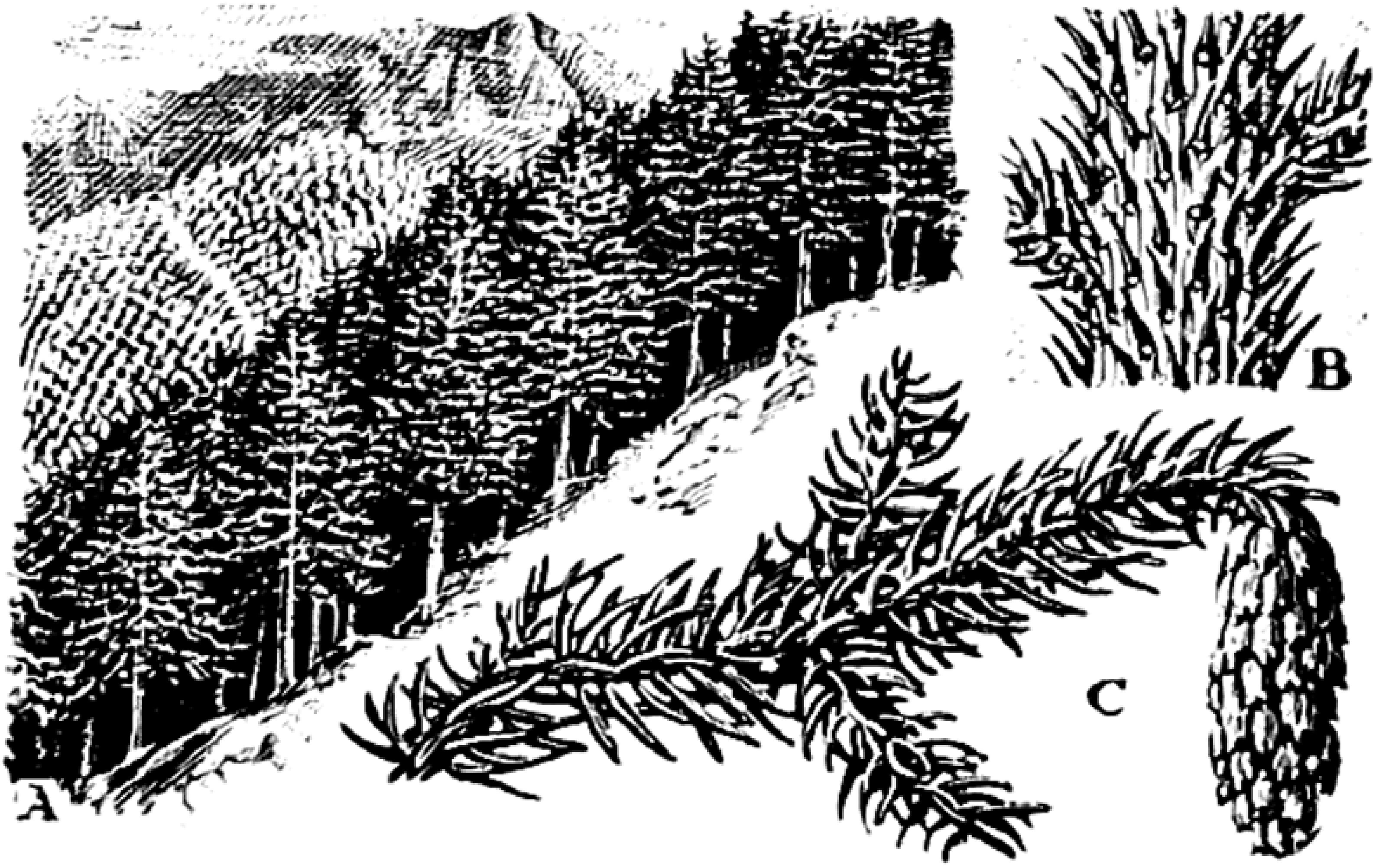


The handsome Scots pine is our only large native conifer. The male flowers (C) and the female flowers (D) are borne at the shoot end. Notice the round young cones (B) and the deeply fissured bark (E).

The timber of our hardy Scots pine is red in colour and it is known as red deal. It is used for floors, rafters, and *joists* in house building, and for all heavy constructional work both indoors and out. You may wonder why softwoods like larch and red deal are more durable than other softwoods like spruce (white deal). The difference depends on the amount of resinous gum that the various timbers contain. These gums preserve the wood because they prevent water from soaking deeply into the grain; thus the timbers of Scots pine and of larch are kept dry by the resin that is in them, whereas spruce wood, which contains little resin, soon becomes waterlogged and rotten. You may be interested to know that the abundant resinous gum in red deal is the main source of turpentine and resin. The turpentine is extracted from the gum by heat, and it comes away from the special boiling pot or 'still' in the form of a vapour which has to be condensed into 'spirits' of turpentine. The hard resin is left behind in the still. Years ago turpentine was manufactured on a small scale in this country, but our home supplies of Scots pine are at present so low that we have to get all our turpentine from overseas—chiefly from North America.

### THE SITKA SPRUCE

The Sitka spruce is by far the most commonly planted tree in our modern woodlands—three out of every ten trees planted in Britain during the past thirty years belong to this species. There is no other tree—either native or foreign, softwood or hardwood—that grows so rapidly on exposed hillsides where the soil is dry and poor. And on the lower slopes it thrives and grows at an extraordinary rate—it has been known to grow fifteen feet in five years of its middle life. In exposed situations Sitka spruce needs to be planted in a protective mixture containing Scots pine because, as you have already learnt, the young tree is easily dislodged by strong winds and it is tender to frost. Once it becomes established, however, it is quite wind firm in even the most exposed places and it is little wonder that the Forestry Commission have planted so much of it. It will stand industrial fumes quite well so that it is useful, not only in remote country areas, but also on the fringes of industrial areas: there is, for instance, a great deal of it growing in the colliery districts of South Wales.



Notice that this fine plantation of Sitka spruce is on an exposed mountainside (A). The thorny leaves are to be found not only on the shoots (C) but also on the trunk of the young tree (B).

The tree came to us from the western seaboard of Canada and it was first planted in Britain in 1831—

just about the time when our network of railways was being laid down; and like its close relation the Norway spruce,[1] the Sitka spruce has long shoots covered with innumerable, short, narrow, and densely packed leaves. The leaves of the Sitka spruce, however, are needle-sharp. It is easy to gather a specimen shoot of Norway spruce, but you will need to wear a pair of gloves when you collect a shoot of Sitka. These stiff and pointed leaves are silvery beneath and they *persist* on the stems for many years. They are retained even on the trunks of young trees so that handling the thinnings from a plantation can be a painful business unless due care is taken: the young poles are as difficult to grasp as a paper of pins. As you know, the Norway spruce is commonly used for Christmas-trees, but Sitka spruce cannot be used for this purpose—it would be far too difficult to decorate and hang with presents! A careful examination of the cone drawings on the next page will provide you with a further means of distinguishing the Sitka from the Norwegian spruce. As you will see, their cones are quite different in appearance.

The white deal of Norway spruce is, as you have learnt, used largely for indoor work—kitchen tables, cupboards, and so on—but Sitka spruce timber is of a higher quality, and it is more suitable for high-class joinery work than for things like kitchen furniture and packing-cases. Some of our larger trees are already over a hundred feet high and have trunks four or five feet across. In another fifty years when the young plantations now growing have matured, we shall have extensive forests full of these fine trees, and our need to buy this popular timber from overseas will diminish.

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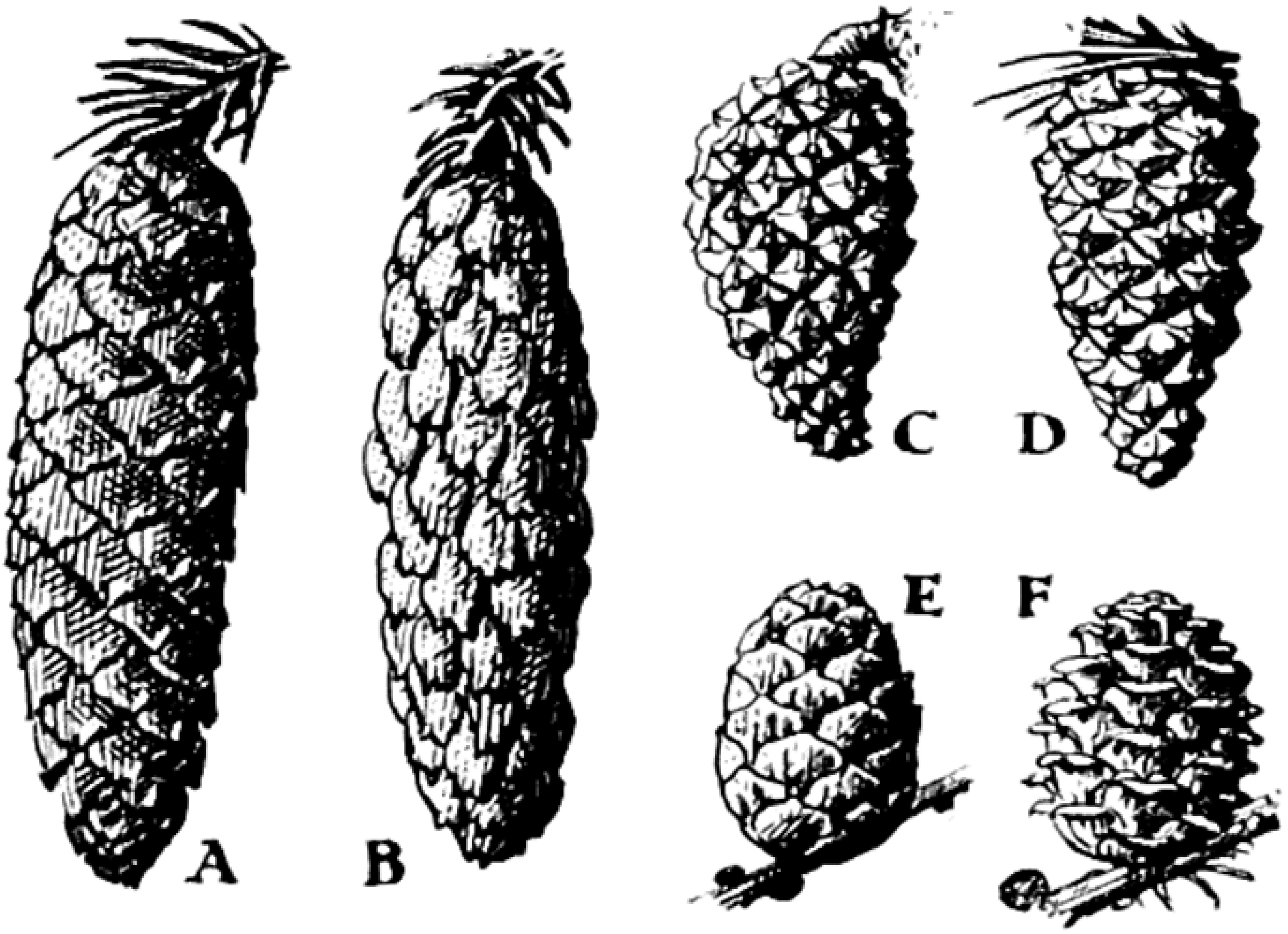
[1] *Rural Studies*, Book II, Chapter 2.



The cones of Norwegian spruce (A) and Sitka spruce (B) hang downwards and they look rather like cigars. But notice the different shapes of their scales.

The commoner pines—Scots (C) and Corsican (D)—have cones that are woody and *pendulous*; but the cone of the Scots pine is rounder in shape.

Larch cones—both European (E) and Japanese (F)—sit upright on the twig. They can be distinguished by the shapes of their scales.

## THE JAPANESE LARCH

The Japanese larch comes from the high mountain slopes of the Far East and was first imported in 1861—more than two hundred years after the European larch. It is not easy to distinguish the two trees. They both send out attractive tufts of thin, fresh green leaves in spring, both bear the attractive pink 'roses' or female flowers, and the male catkins of both trees are small, yellow, globular structures; and on both trees the terminal shoots develop into long and graceful tresses as the summer lengthens. There are slight differences to the observant eye, however; the leafy tufts of the Japanese larch are of a bluish green and the twigs are pale brown, and the tips of their cone scales are bent over so that they are distinctly lipped.

The timber of Japanese larch is almost as valuable as European larch wood and is similarly used for outdoor purposes—telegraph-poles, bridges, boat-planking, the sides of farm carts, ships' masts, railway sleepers, fencing, 'rustic' garden pergolas, and so on. Both timbers are very durable indeed. The wood of both the larches is a pale brick red in colour and its value for outdoor structures has been known for countless ages. Even two thousand years ago the Romans travelled to the northern limits of Western Europe to fetch European larch-trees for building their homes and temples. Most of the larches that you have seen in small woods or in plantations were possibly quite small trees; but when fully grown in a suitable situation the tree is noble and magnificent. Its huge straight trunk—four or five feet in diameter at the base—towers to a height of a hundred and thirty feet or more, finally tapering upwards to the frail shoot at the top. Its side branches—straight and almost horizontal in their early years—sweep gracefully downwards and the young leaves clothe the tree in summer with a tall pyramid of pale green. There are not many such specimens in Britain so that, if you do see one, remind yourself that you are looking at a comparative rarity whose natural home is high on lofty mountain slopes—or on the shores of some northern country where the sun in summer never sets.

## THINGS TO DO

(1) Write a composition with one of the following titles:

(*a*) The Work of the Forestry Commission.
(*b*) A Forest I know Well.

If you do the second one say where the forest is, what trees it contains, the reason they were chosen for planting, and the present work being done.

(2) Answer the following questions:

(*a*) What happened to the native forests of Britain?
(*b*) About what percentage of Britain is at present covered by woodland?
(*c*) How many acres of forest land has the Forestry Commission planted in the past thirty years or so?
(*d*) How do our forest timber trees begin their lives?
(*e*) For what two reasons are thinnings taken from young forests?
(*f*) What class of trees—softwoods or hardwoods—is to be found in most of our forest plantations?
(*g*) Why are broad-leaved trees not planted on a wider scale?
(*h*) Which forest conifer is a native tree?
(*i*) What is the name of the timber that comes from Scots pine?
(*j*) Why do we plant Corsican pine?
(*k*) How can you distinguish between a European larch and a Japanese larch when examining their cones?
(*l*) Why is the Sitka spruce more commonly planted in Britain than any other tree?
(*m*) What is one difference between the Norway spruce and the Sitka spruce?
(*n*) What is the name given to spruce timber and what is the main use of it?
(*o*) Why is larch timber very valuable?
(*p*) Why is larch less commonly planted than spruce?

(3) If there is a young plantation near to your home seek permission to examine the various trees in it and take a *small* twig of each. Make a drawing of these in your Country Book, labelling them accurately and neatly.

(4) Collect as many different cones as you can, find the names of the trees from which they came, and make careful drawings of them in your Country Book. Say where you got the cones.

(5) Find the seedlings or the young plants of at least three different hardwood trees and plant them carefully in a hedgerow. By the time you are middle-aged they will be sizeable trees!

[*Note to the teacher :* Some specimens of granite, sandstone, fossiliferous limestone, and chalk will be helpful for the work in the following chapter.]

# 3

# New Soils and Old Rocks

And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so.

And God called the dry land Earth; and the gathering together of the waters called he Seas: and God saw that it was good.

THE BOOK OF GENESIS, i. 9, 10.

YOU HAVE already learnt that most soils contain numerous particles of sand and silt and clay. Where did these *mineral* particles come from in the first place? They were not always where they now are, for in the 'far backward' of time, countless millions of years ago, the earth had no soil on its surface at all. It was a mass of molten rock rather like molten glass or the molten slag that flows from blast furnaces. There were no hills, valleys, streams, or seas, and the atmosphere was thickly charged with hot, invisible water vapour. But as time went slowly on a great change came about. The earth began to cool and, as it did so, a skin of solid rock was formed on its surface. This skin, however, was not flat and smooth. As you know, whenever a substance is cooled, contraction takes place; and as the earth began to cool in those far-off times it shrank from its former size and the surface skin of solid rock was thrown up into great folds, so that lofty mountain chains and broad valleys came into being. Even so there were no seas or streams, nor were there any clouds; the sun shone and the stars twinkled from a perpetually cloudless sky upon a mass of rock that hardened as it cooled. Many long ages of cooling passed before the water vapour in the air could condense to form the spreading oceans or to feed the torrential rivers with drenching storms.

Those ancient rocks that formed the first crust on the molten earth are called **igneous rocks** [1] because of their fiery origin. They are still in existence, of course, and in volcanic regions new igneous rocks are continually being formed; but apart from occasional outcrops of igneous rock the original crust of the earth is covered by thick masses of rock that have been more recently produced. These more recent, overlying rocks—such rocks as the sandstones and limestones of which many houses and walls have been built in hilly country—did not exist in those first 'fiery' days of the earth's history. Every inch of the earth's solid surface was at that time composed of crystalline rocks of igneous origin. Granite is one kind of igneous rock with which you are probably familiar. Let us have a close look at a piece of 'pink' granite in order to be able to compare it with the more recent sandstone or limestone. Careful examination will show you that the granite is composed of a mass of fused crystals of different colours—some white, some pink, and some quite black. These crystals were solidified into their present shape when the earth began to cool millions of years ago, and they have undergone no change at all during that immense period of time. The more recent overlying rocks of the earth's surface, however, are quite different in structure from igneous rocks such as granite and they have a quite different origin. Where have these newer rocks come from? How were they made, and how were they spread over the surface of the earth? They *must* have been made from the igneous rocks: the vast quantities of material of which they are composed could have come from no other source; but the manner of their formation is a matter of *speculation.* Let us think about it.

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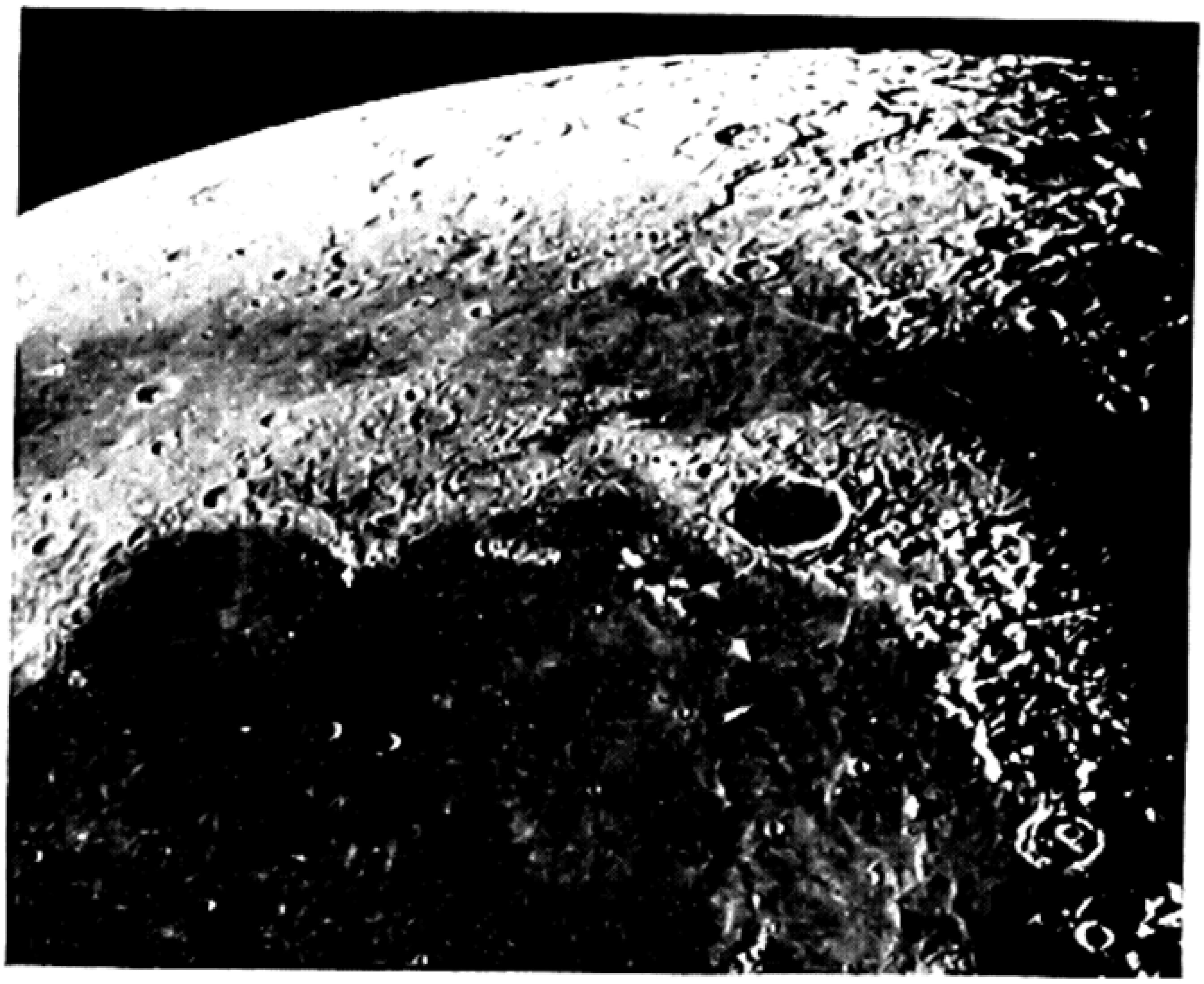
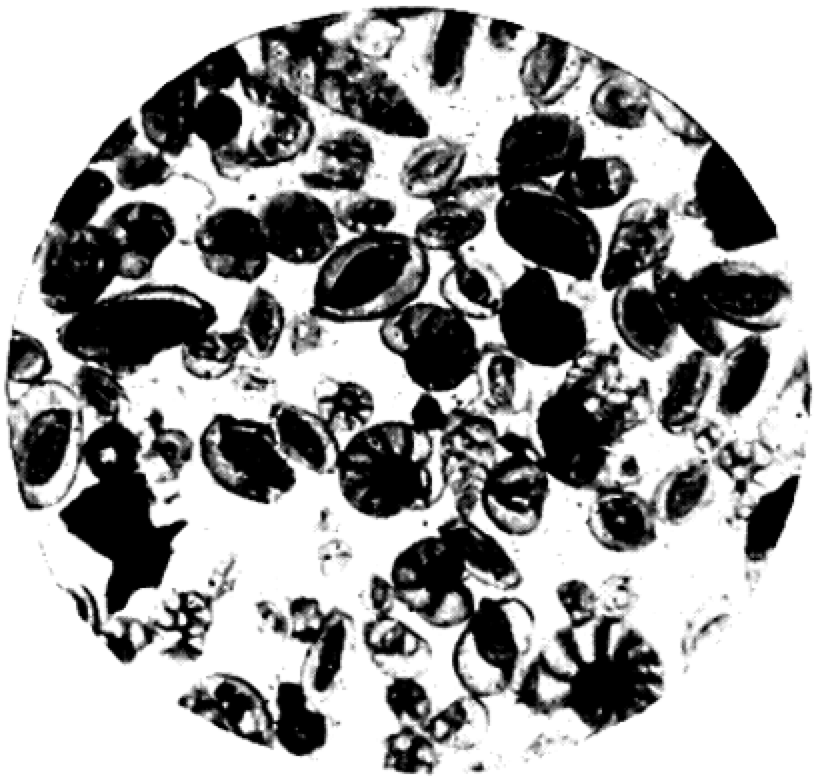
[1] Can you think of any other words that have to do with fire and that begin with the letters 'ign . . .'?



Here is a photograph of the surface of the moon—there are no seas, no streams, no clouds. There was a time—millions of years ago—when the surface of the earth was a similar mass of igneous rock.

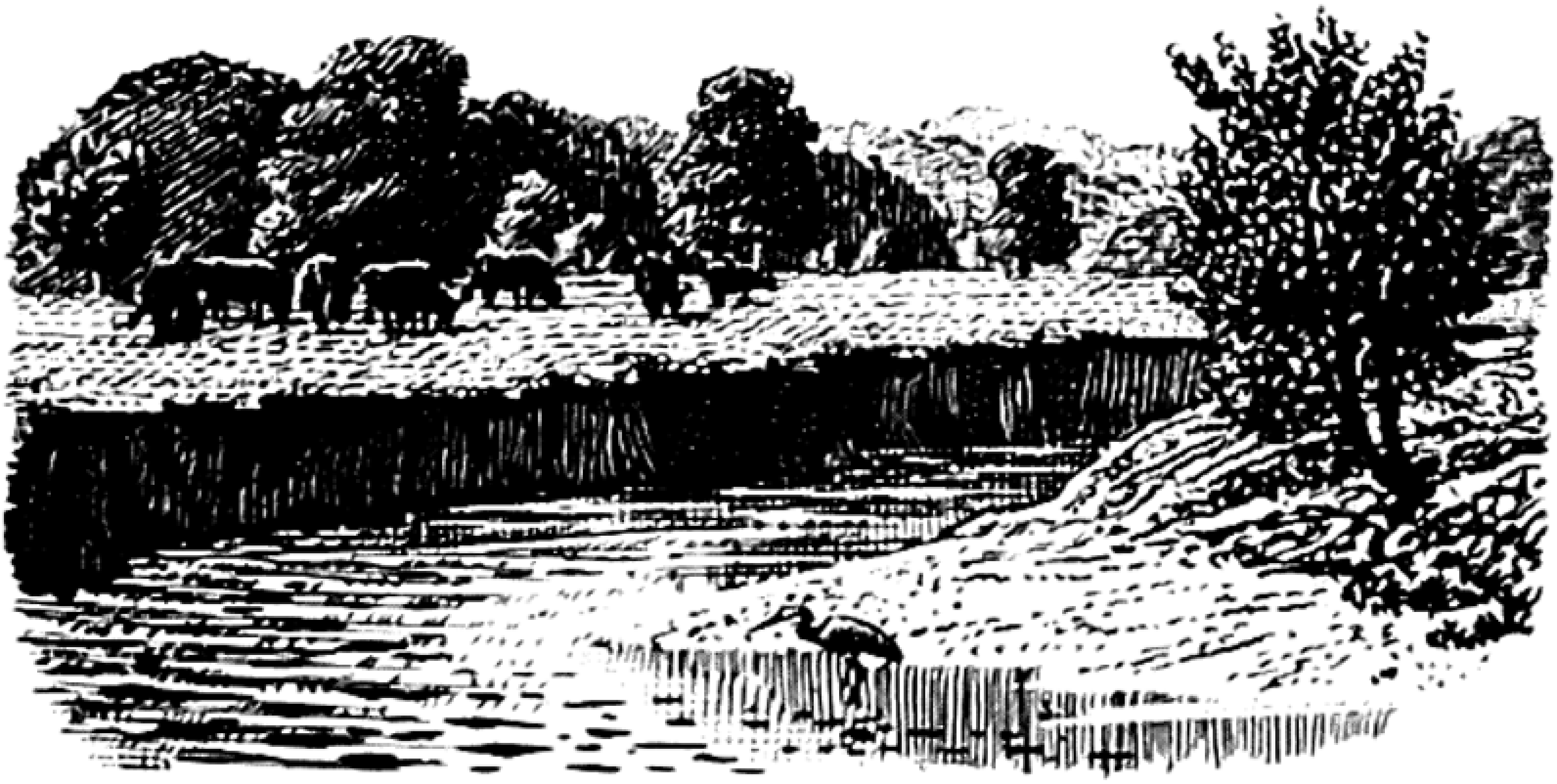
## THE FORMATION OF SEDIMENTARY ROCKS

Careful examination of a piece of sandstone will soon make it clear to you that this more recently formed rock is made up of large numbers of sand particles; it is not a *fused* mass of crystals like granite—the sand particles are minute 'chippings' of rock that have cemented themselves together into a hard lump. Unlike granite, the sandstone did not solidify from molten rock into its present form; the fragments of which it is composed have at some distant time been broken away from igneous rocks, collected together by some means, and pressed into the solid mass that you now see. Some pieces of sandstone actually contain large pebbles of igneous rock and the presence of these pebbles makes it very clear that the particles of which the sandstone is composed were at one time separate fragments. Sandstone is not by any means the only rock that has been formed by the cementing together of numerous particles in this way. There are many such rocks. Some limestones, for example, are made up of numerous particles. So is chalk. But the particles in many limestones and in chalk are not 'chippings' of igneous rocks; they are the **fossil** remains of ancient sea creatures. Some of the **petrified** animal remains in fossiliferous limestone are so big that they can be seen easily with the naked eye, but the fossil shells of which chalk is composed are so minute that they cannot be seen without the aid of a microscope. The fossil fragments of limestone and chalk did not,



When powdered chalk is examined under a microscope, we see that it is made up of countless minute shells.

of course, come directly from igneous rocks, but the materials used in their construction must have come from the earth's igneous crust to begin with, just as the shell on a hen's egg comes from the limestone grit or the oyster-shell chippings you provide her with.



Why is this river bend deep on one side and shallow on the other?

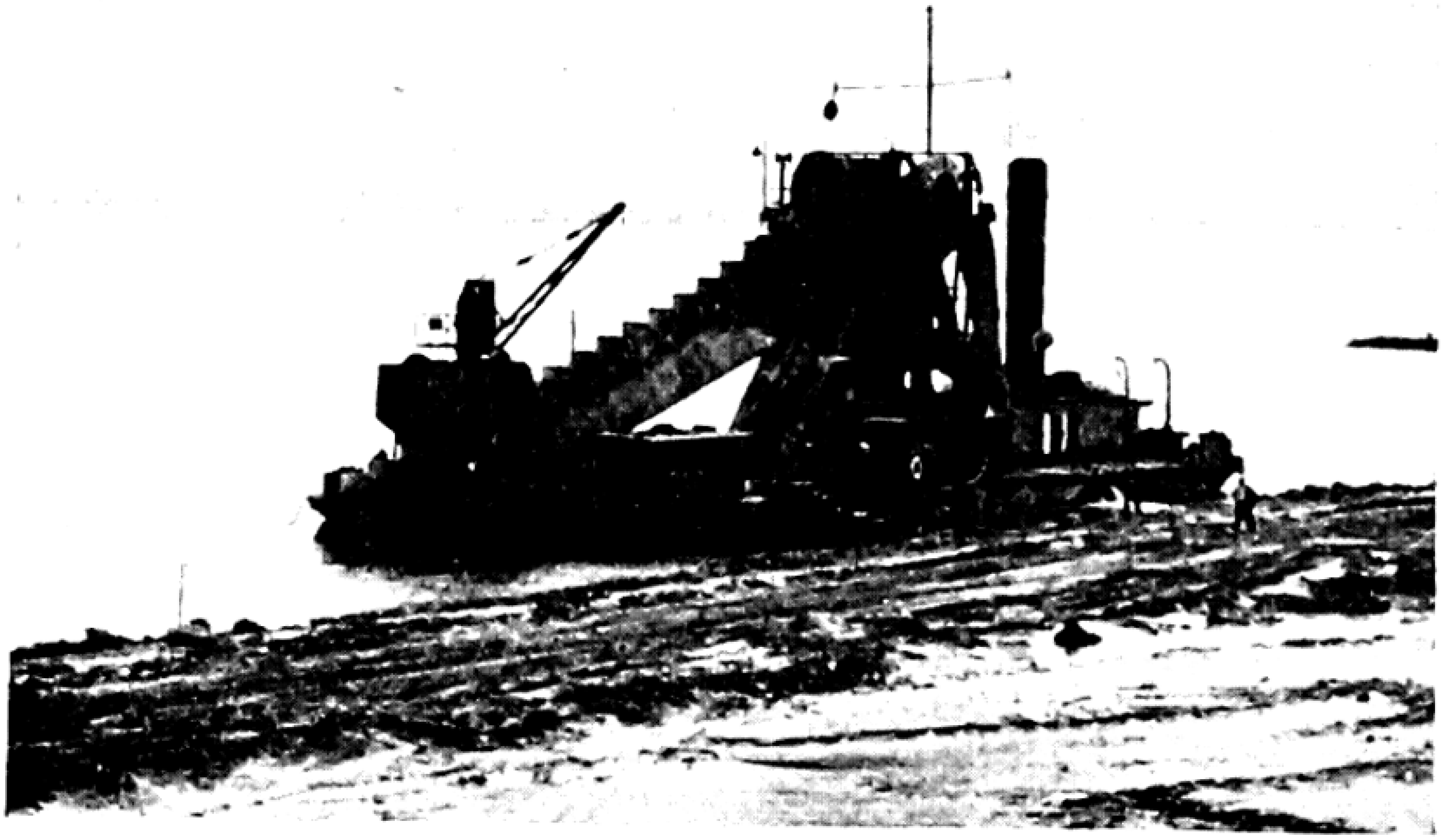
You can quite easily watch the way in which the particles of sand in a piece of sandstone may originally have been brought together if you take a walk along the banks of a winding stream. At any sharp bend you will be able to see two very interesting processes in operation. The bank on the outside of the bend is likely to be quite steep—even overhanging—and the water deep; whereas the bank on the inside of the bend is likely to be shelving and the water so shallow that a considerable sand-bank may stand high and dry unless the river is in spate after heavy rains. Can you explain this difference? Particles of sand are evidently being washed away from the bank and from the bed of the stream on the one side, while the other side is receiving constant deposits of rock particles. These different processes are due to the different speeds at which the water is travelling along the two banks. The distance round the outside of the bend is greater than the distance round the inside so that the water has to travel more rapidly on one side than on the other in order to get round the curve. Indeed it is travelling so fast on the outside that it wears the bank away with its rushing movement and carries particles of sand along with it. What will happen to these suspended rock fragments? As soon as the water reduces its speed they will fall on to the river-bed—the bigger particles first, then the smaller ones further downstream, and finally the minute particles of clay at an even greater distance. So, you see, the water not only carries mineral particles from one place to another, it also sorts them out into their various sizes before they are deposited.

Now let us think about what is happening on the inside of the bend. The water here is moving much more slowly—it is not going fast enough to gather particles of sand and carry them along; indeed the very opposite process is taking place and mineral particles carried down from further upstream are being deposited so that the river-bed at that side is constantly being raised. And indeed, in times of flood, the inside of the bend may well receive such a heavy deposit that it is left high and dry when the level of the river falls again. The result, of course, is that the stream is steadily shifting from its old course and the bend becomes increasingly sharp as time goes on.

Large quantities of rock fragments of all sizes and in all parts of the world are being continuously moved about by water in this way; and when we bear in mind that the process has been in operation for millions of years it is quite easy to understand how almost the whole surface of the earth has become covered with *sediments* of one kind or another. In the course of long ages such deposits of sand or clay are compressed into solid rocks and what we call a secondary or **sedimentary rock** is produced. It is true that some such rocks are formed from rock particles that have been drifted into deep layers by the action of the wind—desert sands are wind-formed and it is clear, therefore, that desert sandstones were not laid down under water. But the great majority of sedimentary rocks are *water-formed* and (with the exception of wind-formed sandstone) all sandstone, limestone, chalk, slate, and coal (which is made up of the compressed remains of swamp plants) were deposited originally under water. *Those parts of the earth where water-formed sedimentary rocks are to be found must all at one time have been covered with water.* The rocks of some of our highest mountains—Skiddaw in England and some of the slopes of Snowdon in Wales, for example—were at one time under water! We know this was so because the summit of Skiddaw and some of the 'shoulders' of Snowdon are composed of water-formed sedimentary rock.

As you travel about the country you will frequently see outcrops of sedimentary rock layers—or *strata* as we call them. You should keep your eyes open for this kind of thing when you are travelling through railway cuttings, or when you see a quarry, or when you see cliffs at the seaside. When sedimentary rock strata were first laid down they were of course in fairly flat, horizontal layers; and this is how you will see them in many outcrops. But they are not always horizontal;

very often they are bent and twisted in all directions—sometimes even standing on end—and it is obvious that at some remote time such beds of rock must have been lifted and distorted by tremendous volcanic movements. The hard strata were bent and folded like soft clay and the tremendous movements that must have taken place to produce such *contortions* give us some idea of the enormous forces that can be exerted by volcanic upheavals. Whenever you look at such contortions of rock you should remind yourself of their cause, and you should remember that when the strata were first laid down, as an accumulation of small particles, they were more or less horizontal.


This dredger is constantly at work—removing sand from the bed of the Mersey estuary. Why does sand collect at the mouth of the river?

The process of rock formation is, of course, still going on. The sedimentation of sand and clay that you saw at the bend of the river was only a small example of *deposition.* Much larger areas of sandy deposit are to be found in many places: especially in river-fed lakes or at the mouths of big rivers like the Mersey, the Clyde, the Thames, the Dee, and so on. As these rivers slow down to meet the sea and the tides, they discharge millions of tons of the sediment that they have brought downstream. The result is that their large estuaries are in constant danger of being 'silted up.' If sea-going ships use the rivers, the sailing channels have to be kept deep and navigable by constant dredging. Special boats called dredgers are ceaselessly at work digging out the deposited sand and silt and carrying it further out to sea.

## THE WEATHERING OF IGNEOUS ROCKS

What caused the igneous rocks to crack and crumble into the fragments that make up the sandstones and the clays? This process of *disintegration* is due to the combined effects of water, wind, frost, the heat of the sun, and so on; and rocks that are destroyed and fragmented by these agencies are said to be *weathered.* The combined chemical action of water and air breaks up some of the crystals in the igneous rocks and a slow process of 'rotting' sets in. This takes place inside as well as on the surface of the rock because no rocks are *impervious* to water; even granite is penetrated by the rain so that it weathers quite readily. The disintegration of the rock is hastened by extreme changes of temperature. When a hard frost comes along the water inside the rock freezes and expands; and the rock is burst open just as the heavy clods of clay land are broken down in wintry weather. If the weather gets very hot, the water again expands and splits the loosened granite by the force of this expansion. The particles that are thus formed are washed down the hillsides by heavy rain and are carried eventually into rivers, lakes, and seas. Such processes of weathering and sedimentation have in times long past produced most of our sandstones and all our clays.

The particles from disintegrated granites and other igneous rocks are not all of the same size of course; nor are they made of the same substances. Some of them are sand particles and some are particles of clay, and there are many differences between these two things, as you know. Sand is made of a glassy substance called *silica* and its particles are often quite large. Clay particles on the other hand are minute and they contain a good deal of aluminium. Furthermore the tiny particles of clay can absorb large quantities of water whereas the sand particles cannot. You should take another look at a piece of 'pink' granite and make sure that you can recognize the three different kinds of crystals that it usually contains. You will see numerous large white crystals of a mineral called *quartz*. Quartz is composed entirely of silica—indeed fragmented quartz is one of the main sources of the sand we find in soil. In addition, you are likely to find some dull red crystals. These are crystals of a mineral called *felspar* and it is from the weathering of felspar that a good deal of the clay in soil has been derived. You will also see some tiny black glistening crystals. These are composed of a mineral called *mica* and the weathering of mica also produces clay. The weathered granite, you see, produces the two important but quite different mineral particles that are contained in the majority of soils—both sand and clay. Many other kinds of igneous rocks produce sand and clay when they are weathered, but granite is one of the important ones.

## LIFE APPEARS ON THE EARTH

For countless ages of time the formation of sedimentary rocks went on; but many millions of years were to pass before any soil was formed. The fragments of igneous rock were distributed far and wide and deposited in immense quantities—in the shallow parts of the sea, in vast lakes, and in the estuaries of great rivers. Slowly—very slowly—the beds of hard rock that we see to-day were built up. But not until living things began to appear was it possible for any soil to be made. As you know, soil contains not only mineral particles of sand and clay; it also contains humus—and humus, as you know, is made only from the dead remains of plants and animals. When did living things first begin to appear? Can you think of any clues that scientists could look for in order to solve this problem? Remember the fossil shells that are to be found in fossiliferous limestone and in chalk. Those fossils tell us quite clearly that there was life in the seas at the time when those rocks were being layed down. Are there any sedimentary rocks that are older than the limestones or the chalks? If so, do those older rocks contain any fossils of living things?

Many of the sedimentary rocks are indeed a great deal older than the chalks and limestones; and even the very oldest of them—various kinds of sandstone chiefly—do contain a few fossils. This proves to us that some simple forms of life appeared on the earth at about the same time as the sedimentary rocks began to be formed. As time went on there was an increase in the number of living things—and then, as now, plant life was the most abundant. The earlier plants were very simple organisms, but the time came when plants bearing roots were developed, and it must have been at about the same time that soil as we think of it began to be formed. On farms and gardens we dig or plough a great deal of humus into the soil; but soil that develops naturally gets its humus from the dead plants and animals that grow in and upon it.

Those early natural soils must have been very shallow indeed, for the earliest rooted plants were small and their roots did not penetrate far into the ground. With the passage of immense periods of time, however, more and bigger plants came into existence; and the best of all cultivators—the plant root—began to deepen the natural soils and to make them more fertile by the addition of increasing quantities of humus. This increase of humus provided sustenance for increasing numbers of nitrogen bacteria so that more plant foods became available and even larger numbers of plants could grow. The change of scene from bare stretches of rock, mud, and sand must have been very slow; but it was indeed a miracle of creation—first the molten earth, then the solid igneous rock, the flooding of the seas, the weathering of the granites, the sedimentation of sand and clay over most of the surface of the earth, and then, most miraculous of all, the first appearance of tiny forms of life. There was the gradual emergence first of small and then of larger plants: and all the time a deepening and enriching of the primitive soil. It was not until a green mantle of flourishing plants covered the face of the earth that the bigger and more complicated animals could appear, for there was no food to support them.

Millions of years ago reptiles such as these inhabited the swamp lands of the earth. How do we know this? What do we call the flying reptiles?

ANIMAL LIFE THROUGH THE AGES

The earliest forms of animal life lived in the rivers, in the lakes, and in the sea. We know that this was so because, in the oldest sedimentary rocks, we can find only the fossil remains of numerous water creatures. The fossil skeletons of land animals and of birds—skeletons that were washed into the lakes and seas—are to be found only in rocks of later periods. The oldest strata in which the bones of such animals are to be found were laid down not long after the period when the great forests that formed the **coal measures** were flourishing. First came the small reptiles—the ancestors of our modern snakes and lizards—and after them the gigantic reptiles, pictures of which you have no doubt seen. We have given to those strange-looking and enormous animals such names as the Brontosaurus, the Diplodocus, and the Ichthyosaurus. Those prehistoric monsters were as huge and cumbersome as the names we have given them. Some of them lived on the luxuriant vegetation of the warm swamp lands, and some of them—the carnivorous ones—lived on the flesh of their neighbours; but they have left no descendants behind them, for, like many other creatures that were created down the long ages of time, they were suited only for the era in which they lived. Their fossil remains, however, are still to be found; and **geologists** (men who study the rocks) are able to tell us when they lived and what they were like. Somewhere about the same time, the first flying animals made their appearance. These creatures of the air were not true birds, but they were the ancestors of our modern birds—they laid eggs, had a bill instead of a mouth, and their forelimbs consisted of two long, pointed wings; but they were not feathered. These flying reptiles were called Pterodactyls and there were many kinds of them varying in length from several inches to as much as four feet. We think that they lived largely on fish and other sea food because their remains have been found in beds of chalk; and since chalk was deposited only in very deep sea-water far removed from the land these primitive birds must have been able to fly for great distances over water—a fact which suggests that they had feeding habits similar to those of many of our modern sea-birds.

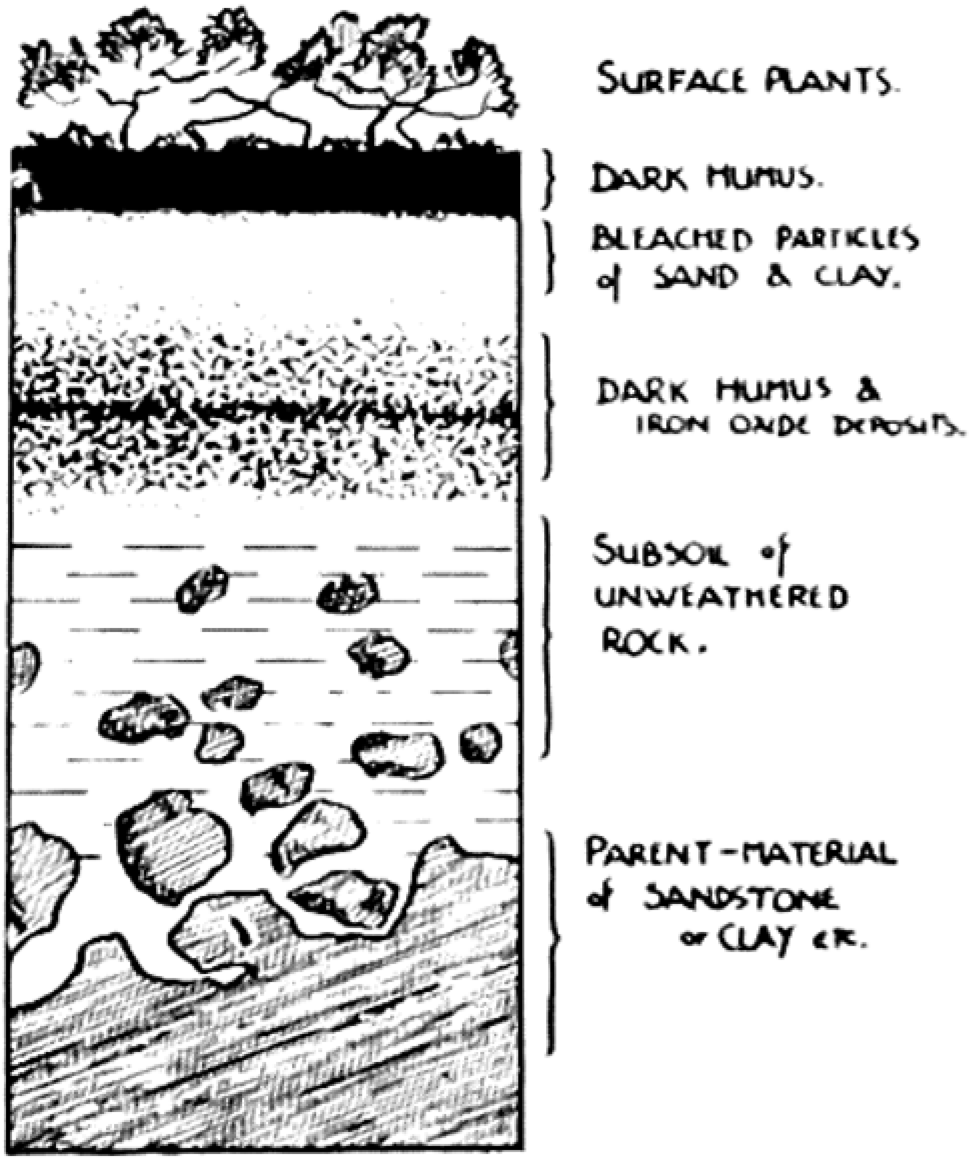
How do we know that there were living creatures on the earth long before primitive man made his appearance?

Many millions of years were yet to pass before the first human beings appeared on the earth; indeed it is thought that man is at the most only 1,000,000 years 'old' and modern man very much 'younger' than that. We are truly the newcomers to the earth. There had been other forms of life on this globe countless millions of years before man appeared at all! You may wonder how we have gained our knowledge about man's first appearance. Again it is a study of the rocks and the fossils they contain that has supplied us with the information. Man's remains have been found only in the most recent 'rocks' of all. These recent deposits are not yet old enough to have become solid and compact; they consist of loose sands, clays, and loams, and it may seem strange to you to hear them called rocks. Not many skeletons of our earliest human ancestors have been found—probably because there were very few of these early men and it is probable also that the dead bodies of most of them were eaten by carnivorous animals. One important discovery of parts of an ancient human skeleton of prehistoric times was made at Piltdown in Sussex, and a recent (1951) important discovery of a similar nature has been made at Peking in China. The research, you see, continues; and the more we know about the history of the earth, the more astonishing and impossible this story seems to be. Perhaps the most amazing happening of all was the first appearance of tiny *living* things. We are not able to explain how this happened. Life keeps its secret; it is a complete mystery to us.

## SOILS AND SUBSOILS

If we dig down through a natural, uncultivated soil so as to expose a flat vertical surface some two or three feet deep we shall be able to see the process of soil formation in operation. In some places the excavations for the laying of drainage pipes, water supplies, and so forth will expose a suitable **soil profile** of this kind for your inspection, but you must be sure that you are examining a soil that has not been cultivated. Let us examine the various levels of such a profile and measure their thicknesses. To begin with you should choose a fairly free-draining soil and you should make a careful diagram of what you see.

At the very top you will find the layer of growing plants, and immediately beneath this a surface layer of dead plant remains, together with some black, decayed humus. The thickness of this layer of humus will depend on the sort of vegetation growing on top; beneath such small plants as heather it will be fairly thin, but on the floor of a forest it will be considerably thicker—several inches thick maybe. Take hold of some humus and smell it. It has a sweet and wholesome odour that is very attractive. Indeed it reminds us of the pleasurable smell of the earth on a warm day in the early spring when the 'time of the singing of the birds is come'; whenever nature humifies the dead remains of living things the result is always clean and wholesome in this way. Measure the thickness of the humus layer and enter the result in your notebook. Beneath the humus comes the soil proper, the soil that contains particles of sand and clay. Frequently, though not always, the first thin layer of this part of the profile is made up of grains of white sand. Can you explain this? Before you attempt to do so you must become acquainted with the results of a simple experiment which you can do when you get back to school.


SURFACE PLANTS.
DARK HUMUS.
BLEACHED PARTICLES of SAND & CLAY.
DARK HUMUS & IRON OXIDE DEPOSITS.
SUBSOIL of UNWEATHERED ROCK.
PARENT-MATERIAL of SANDSTONE or CLAY etc.

The soil profile that you examine may differ from this in several respects, but your diagram should be made in this way.

*Experiment.* Put a teaspoonful of brown sand into a jar and cover it with some dilute hydrochloric acid. If it is left to stand in the acid for some time and then washed, the sand becomes quite white. This is because the thin covering of iron oxide that made the sand look brown has been dissolved away by the hydrochloric acid. The silica of sand is not brown at all—it is white.

You have already learnt that the nitrogen bacteria that are present in humus produce small quantities of weak acid. The acid from these bacteria gets washed into the soil by the rain, and if there is no lime in the soil to neutralize it this acid will wash the iron oxide from the topmost particles of sand as it drains over them. If there is no such layer of white sand in the soil that you are examining you should search about under some plants of heath or heather: you will certainly find it there because the heaths and heathers will flourish only on soils that do not contain lime or chalk.

Make a note of the thickness of the white sand layer, if it is present, and then inspect the profile further down. The first few inches will be considerably darkened by the presence of humus. Plant roots of countless generations of plants have died in the soil and have been humified; and in addition a good deal of surface humus has been washed down by the rain. Humus, unlike the dead plant and animal remains that have not rotted, is a colloid and it is soluble in water so that it can readily be washed into the soil spaces by drainage water. The further down you look the less humus you will see, and at a depth varying from 3 inches to 6 inches or thereabouts you see little but the brown mineral particles of the subsoil with very little evidence of humus at all. Beneath the subsoil is the original rock, the **parent material** from which the soil you are examining has been formed. Perhaps this is sandstone—or it may be a solid clay, a loose sand, an open gravel, or even a solid limestone or a solid chalk. The land on which you stand was at one time devoid of any vegetation whatsoever. There was no soil, but only an expanse of the parent material that you have found at the lower end of the soil profile.

If the soil you are examining is very acid you may find in the upper subsoil a hard thin layer of sandstone that breaks as easily as a biscuit. Some people give the name 'fox bench' to this layer which has been formed by the downward passage of the acid water that washed the iron oxide from the thin top layer of white sand. The dissolved iron compounds that the acid drainage water carried downwards have been redeposited at a lower level and have cemented some of the subsoil particles into a thin layer of stone. A soil that has this hard 'pan' is called a **podsol**. Such podsols are formed only from rocks that contain no lime, and most podsols will be found in free-draining, sandy country such as on dry heather moors. There are, of course, many other kinds of soil profile to be found, but in the profile of any uncultivated soil you will be able to observe:

(1) The dead but undecayed vegetation at the surface.
(2) The layer of surface humus.
(3) The top soil containing humus.
(4) The subsoil containing little or no humus.
(5) The parent material underneath,

and your diagram should show each of these soil layers very clearly.

## THE LAST GREAT ICE AGE

In the lesson on the formation of sedimentary rocks you were told that water and sometimes wind were the *agents* of distribution of rock particles, but no mention was made of ice-formed rocks. Most of the sedimentary rocks were indeed water-formed, but much of the lowland country in Britain, north of a line joining Bristol to London, is covered with a deposit of soft 'modern' rocks that were not laid down either by water or by wind. These clays and sands were deposited by ice! For many thousands of years most of the surface of the British Isles was covered by a thick sheet of ice much as the poles are covered by ice to-day. Indeed the ice sheet and the glaciers that lay across Britain were an extension of the polar ice cap which for a long period of time—known as **The Last Great Ice Age**—was much larger than it is now. The enormous glaciers that crept down from the mountainous regions—from Scotland, from the Lake District, from the Pennines, and so on—removed vast quantities of rock from the mountain slopes, and this fragmented material was carried down to lowland areas by the slow-moving ice.

Then came a great climatic change. About 11,000 years ago the ice cap began to 'retreat' to the north, the great glaciers melted, and all the fragments of rock—all the boulders, sands, and clays—that they had picked up on their southerly journey were left behind as surface deposits. The Vale of York, for example, and the Cheshire Plain are almost entirely covered with deep deposits of clays and sands. These *glacial* deposits are the parent materials of most of the soils of Cheshire and of the Yorkshire Vale, and the same is true of large areas of lowland in midland districts. It is easy to recognize there glacial sands and clays, because they usually contain numerous pebbles and large boulders that have not been ground to finer particles by the scouring ice. Indeed glacial clays are called **boulder clays** for this reason. Not all clay soils are derived from boulder clays of course. The clays of those parts of southern England that were not covered by the ice were laid down in great lagoons of water and you will find few pebbles in them. The clays of the Weald of Kent, for example, and the clays of the London Basin do not contain glacial pebbles, but if you seek in a clay field further north you will surely find them. 'Lucky stones' these pebbles used to be called by country children.

This northern stream has worn its course through a deposit of boulder clay. About how long have these boulders been in their present position?

As you go about the more northerly parts of Britain —North Wales, Northern Ireland, the Midlands, and the rest of the north country—you should examine the banks of streams and the exposed surfaces of quarry workings for deposits of sand and clay that contain pebbles and boulders. When you find any you may be sure that you are standing where a great sheet of ice once ground its way slowly along; and the deposits you find were left there by the ice when it melted at the end of the last Great Ice Age.

In hilly and mountainous country you may find these glacial deposits in the valleys, and as you cast your eyes towards the hills and peaks you will be able to see further evidence of the presence of this ancient ice cap. Compare the shoulders of the lower hills with the mountain peaks. The hills and slopes have been smoothed and rounded by the friction of the glaciers, but the peaks are craggy and jagged because they stood out above the ice. If you let your imagination wander you will be able to re-create in your mind a picture of the snowy wastes in those far-off glacial days. Our north country was held in the grip of frost for countless centuries. In those days there was not a tree to be seen—nothing but ice, blizzards, and a few jagged peaks of rock. It is strange to think that the

In the last Great Ice Age much of northern Britain was moulded to its present shape by the scouring weight of enormous glaciers such as this. How far south did the ice cap reach?

landscape of northern Britain as we know it to-day was being slowly carved and ground into shape beneath that frozen wasteland. Yet so it was. Barren and desolate beneath that weight of grinding ice lay the hills and valleys that we know so well.

## THINGS TO DO

(1) Write a composition entitled 'The Origin of Soil.'

(2) Use single sentences to answer the following questions:
  (*a*) What are igneous rocks?
  (*b*) What are sedimentary rocks?
  (*c*) What kind of a rock is granite?
  (*d*) What kind of a rock is sandstone?
  (*e*) When did the formation of solid igneous rocks begin?
  (*f*) What is a fossil?
  (*g*) How do we know that the summits of some high mountains are made of rock that was at one time under water?
  (*h*) Why do rivers often deposit sand and silt at their mouths?
  (*i*) In which rock may quartz be found?
  (*j*) What important material comes from felspar?
  (*k*) What is meant by the parent material of a soil?
  (*l*) What force rounded the shoulders of some of our hills?

(3) Write a paragraph in your Country Book describing the various layers of the soil profile you have examined. On the opposite page draw a rectangle one inch wide and six inches high. Working from the top downwards make an accurate scale diagram of the various materials in the profile. Use faint colours to distinguish the various levels and put some plants above the top line to indicate the growing herbage.

(4) Find out the parent material of the soil on a farm near your home and describe how you think this parent material was formed.

(5) In what two different ways were the clays of northern and southern Britain deposited?

# 4

# Let's Try It Out

## SOME GARDEN EXPERIMENTS

If you are successful in all you do, you cannot also battle magnificently against odds.

EDWARD CARPENTER.

IF YOU listen to the conversations of country folk you will often hear them discussing the best ways of growing the flowers and crop plants of their farms and gardens. All country work requires considerable skill if it is to be well done; and if the result of their labour reaches the high standard of excellence at which they usually aim, most country people display a good deal of likeable pride. There is, however, no one best way of producing a good crop of this flower or that vegetable—the methods that work quite well in one garden may produce mere failure in another because of differences in the nature of the soil. No two soils are exactly alike, and for that reason no two gardeners or farmers ever work in exactly the same way. The *general* ways of doing things are, of course, very similar, but if the gardener is to get the best result from his work he must know more about his own soil than any one else can tell him—however expert his informer may be. The same is true of the farmer; and in the long run it is a combination of experience and experiment that produces the best returns from any particular piece of land.

## AN EXPERIMENT WITH MANURES AND FERTILIZERS

Suppose you wish to find out the best manurial treatment for some particular crop in your garden. You will need to choose a crop all of which can be harvested and weighed on the same day—or, at most, on two successive days. Summer cabbages are one of the best to try. Unless you can be sure of buying the plants in April you should yourself sow seeds in January, either in a greenhouse or in a frame; and the tiny plants should be pricked out to three inches apart as soon as they are big enough to hold between your thumb and finger. They must be planted out into the garden plot in mid April, and they will be suitable for cutting and weighing by the end of the summer term.[1]

Why are these young cabbage plants being 'raised' under glass?

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[1] In 'late' northern districts it is better—in order to get a result by the end of the school year—to use spring cabbage for this experiment. If the young plants are got in by mid October, the manurial treatment is exactly as outlined for the summer cabbage—except that it is important to withhold the application of the sulphate of ammonia until the beginning of April.

You can refer to any gardening book for the best general treatment of the crop. Your purpose is to concentrate your attention on the best manure to use for cabbage in your particular garden—and you will not find this in books. There are many different combinations of manures that could be used, but let us keep the number of possible mixtures to three. If we grow some of the plants without any dressing at all we shall be examining a total of four soil treatments:

**A.** No manure.
**B.** Farmyard manure only.
**C.** Chemical fertilizer only.
**D.** Farmyard manure plus chemical fertilizer.

Now—what decisions are necessary before we can set to work? Let us think of the arrangement of the experimental plot to begin with; we shall need to decide what size of plot to choose and then we shall have to divide it up into four equal parts each of which will be treated in one of the above four ways. You must take care of course not to choose a piece of land the various parts of which have had different treatments in the previous three or four years. If you did, some of the *residual* manures of previous dressings would spoil your results. What you wish

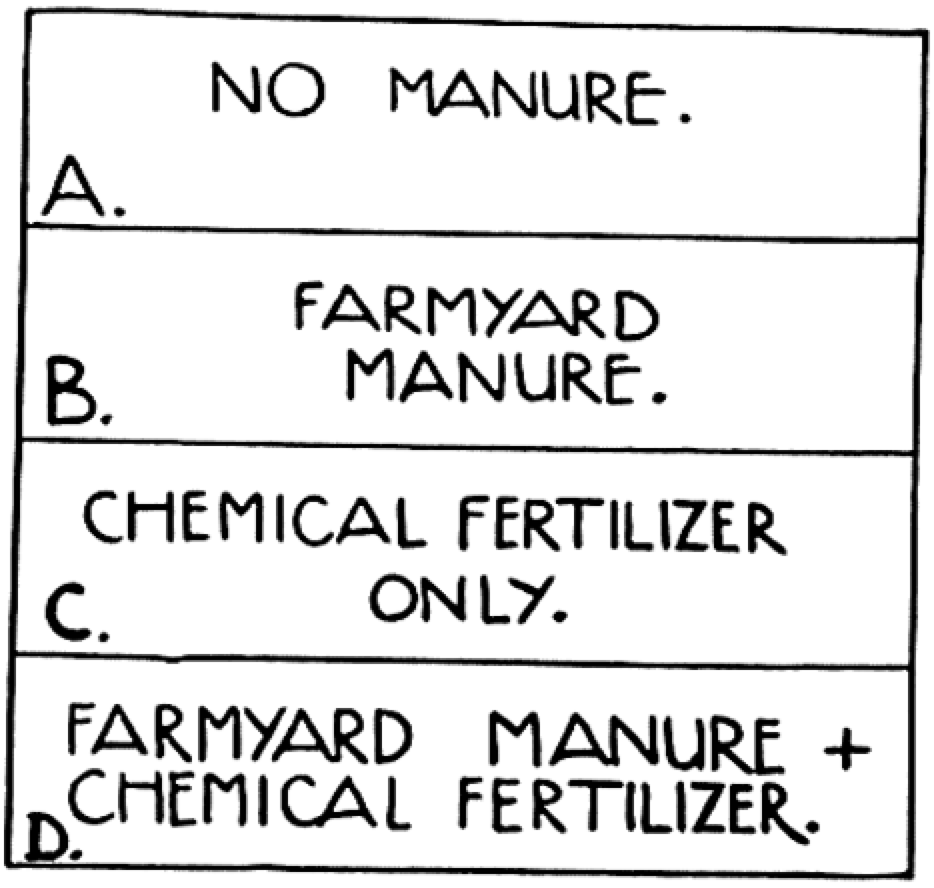
NO MANURE.
A.
FARMYARD MANURE.
B.
CHEMICAL FERTILIZER ONLY.
C.
FARMYARD MANURE + CHEMICAL FERTILIZER.
D.

Fig. 1.

to test is the effect of your four chosen dressings and those alone.

You could split the plot up into four strips as shown in Fig. 1. Will this be satisfactory? If you were quite sure that the soil was of the same quality all over the plot, the strip arrangement would be quite suitable; but it is quite possible that there are soil variations even on a small plot of land, the soil at one end being deeper or richer than the soil at the other. A poor crop on one strip might be the result, not of your treatment but of the soil itself. How can this difficulty be overcome? We *discount* soil variation by using what is called the **Chessboard Method.**

This scheme requires you to choose a square plot which is divided up into sixteen equal squares as shown in Fig. 2. Each of the four different manurial treatments is applied, not on to one long strip of your plot but on to four scattered squares of the 'chessboard.' There are various ways of scattering the treatments, but whichever arrangement you choose no one series of squares, either vertical or horizontal, should contain more than one square treated in a particular way. A possible arrangement is shown by the lettered squares in Fig. 2. Each letter represents one of the manurial treatments you have chosen: the squares labelled **A** receive no manure, those labelled **B** receive

| | | | |
|---|---|---|---|
| A | B | C | D |
| B | C | D | A |
| C | D | A | B |
| D | A | B | C |

Fig. 2.

farmyard manure only, and so on. In this way any variations of soil in the garden will affect all the treatments equally. The four **'B'** crops, for example, will have been grown in various parts of the garden so that the total weight of the **'B'** harvest will represent the effect of the manurial treatment, and will not be due to a peculiarity of the soil in any particular section of the plot.

## THE PLOT IS CAREFULLY MEASURED

A square whose sides are four feet long is of a suitable size for effective manurial treatment; and as you will also need to have paths a foot wide between the squares, your chosen plot should measure about twenty feet along each side, the actual sizes depending on whether or not a permanent path runs along one side.[1] You must decide on the exact size of the experimental plot to begin with, and when you have done so measure it out on the garden very accurately. Mark each corner of the full plot with a stout peg that is driven firmly into the soil for a distance of about one spit. When you are sure that these corner pegs are rigid, surround the plot with a *tight* garden line, attaching the line securely to each peg. This line should remain in position until the crop is planted. The task of marking off the chessboard squares and the *intervening* paths requires a great deal of patience and care. You will need twenty-eight rather smaller pegs and these should be firmly inserted round the whole plot at distances of one foot and four feet alternately

[1] If your experimental plot is rectangular but not square, you can still use the chessboard method, but you will need to cut your scatter plan (Fig. 2) into two halves which can be placed end to end.

along each side. Some strong string or binder twine can then be attached from each peg to its partner on the opposite side of the plot. These strings, which should be quite tight, will lay off the plot into squares and paths; and while the strings are still in position their patterns can be carefully marked in the soil with spade cuts. When this has been done, the cross strings and the smaller pegs can be removed. It is quite essential for you to be very particular about this lay-out, otherwise your experiment may get out of hand. In any case a garden should have a neat appearance or be left alone: a job worth doing at all is worth doing well—slovenly work on the land is always an eyesore, and country people do not approve of it.

Now for the manuring of the various squares. You will have adopted your scheme of *scattering* the treatments, and this should be neatly copied into your Country Book and carefully titled. The manuring of all sixteen squares needs to be done during the same week, and not more than a day or so before the planting—otherwise a portion of the nitrogenous fertilizer which is to be applied in this experiment may be washed out of the soil. When plants are growing, however, they absorb the nitrogen, and prevent its wastage, as you know.

What about quantities? The following mixtures will prove suitable, though you may choose alternative fertilizers if you wish. There are as you know several materials that supply each of the three important plant foods—nitrogen, phosphorus, and potash. Whatever mixture you adopt, make a careful note of it alongside the plan in your Country Book:

### (B)

### *Farmyard Manure, well rotted*

Every '**B**' square needs about one barrow load, and you must take care to give the same amount to each of them.

### (C)

### *Chemical Fertilizer Mixture*

Mix together immediately before use:

| | |
|---|---|
| Sulphate of ammonia | 8 oz. |
| Superphosphate | 12 oz. |
| Sulphate of potash | 4 oz. |

The mixing should be very thorough indeed. If the sulphate of ammonia or the superphosphate has gone lumpy in the bag it must be ground loose again before you do the mixing; there must be no lumps at all. Six ounces of this mixed fertilizer will be dressed on to each of the four '**C**' plots and you have just the right amount for this purpose. Notice the ratio of the separate fertilizers in this dressing: there are two parts (by weight) of sulphate of ammonia, three parts of superphosphate, and one part of sulphate of potash.

### (D)

### *Farmyard Manure plus Chemical Fertilizers*

In order to dress the four '**D**' squares you will need first of all to dig into each one of them the same quantity of farmyard manure as you apply to the '**B**' squares, after which each one will receive 6 oz. of the same mixture of chemical fertilizer as you give to the '**C**' squares.

All the squares should be thoroughly dug, and those that are to receive the farmyard manure should have this manure incorporated at a depth of one spit. When all the sections are thoroughly tilled and quite level, the inorganic manures may be dressed evenly on to the appropriate squares and thoroughly raked in. See that your rake teeth get down to a depth of three or four inches, and take care to put the whole of each dressing only on to the square it is intended for; and do not spill any on to the paths. It is quite easy to make a mistake at this stage by putting fertilizer on to a wrong plot. If you enter each dressing on to your plan as you go along, you will avoid becoming confused and there will be no errors. The '**A**' plots of course receive no manures at all: they are what we call *control plots*, and the weight of crop from them will tell us whether it was worth while manuring the land at all. On a suitably cloudy day in mid April when the soil is moist, plant out your 'greens.' Set them eighteen inches apart in the squares, leaving six inches of soil along each side. In this way you will get nine cabbages on each small plot (Fig. 3).

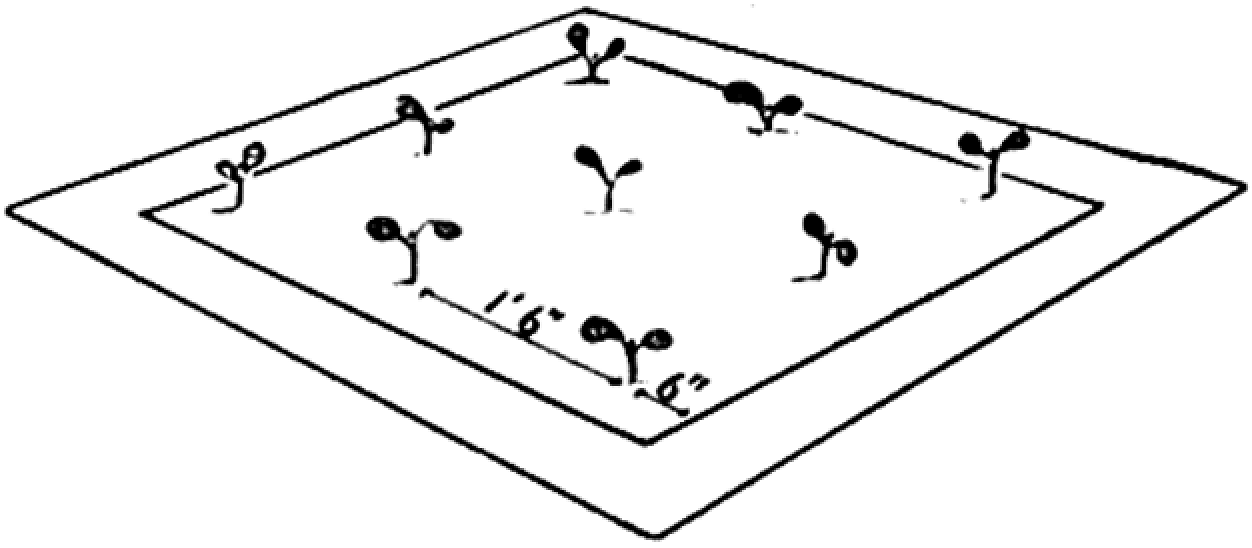

Fig. 3.

There will be twelve dozen plants altogether and by mid July they will have begun to 'heart.' They would of course go on growing, but the end of the school year is near and you need to check your results. Cut them all on the same day and enter the total weight for each of the four treatments—**A**, **B**, **C**, and **D**—in your Country Book, making suitable comments on the results.

*Precautions.* When carrying out a big trial of this kind, it is necessary to guard very carefully against the failure of individual plants—several cabbages attacked by finger and toe disease (club-root) or the cabbage-root fly would spoil all the results completely. For this reason you must guard carefully against attacks of these things even more thoroughly than you do when growing 'greens' as part of your normal gardening programme. If the plot needs lime it should be thoroughly dressed with ground limestone several weeks before you commence work on the experiment—it would be even better to get the liming done in January as you must avoid bringing the nitrogenous manures into direct contact with it. If you allow lime to mix with the sulphate of ammonia or with the farmyard manure much of the nitrogen in these fertilizers will be lost to the atmosphere—it will escape as a gaseous ammonia. The lime, however, is very important as it checks the ravages of club-root. In addition you should take care either to get plants that are not infected with club-root or you should grow clean plants for yourself. Any book on vegetable gardening will tell you how to raise young plants. If you take care to use only a sterilized seed compost and a sterilized potting compost[1] for your seeds and seedling transplants you will ensure complete freedom from club-root. As a final precaution against club-root spores which may be present in the garden plot, dress the roots of each plant at the time of transplanting with a little club-root control.

Attacks of the cabbage-root fly can be prevented by placing a piece of tarred felt round the stem of each plant, at soil level, as soon as it is planted. The cabbage-root flies lay their eggs on the soil near to the cabbages and when the young larvae hatch out they make their way to the cabbage roots on which they feed. The felt disk keeps the fly away from the soil that is near to the cabbage stems and no eggs are laid.

### AN EXPERIMENT WITH POTATOES

The common way of preparing 'seed' potatoes for planting is to put them—rose end upwards—in boxes in January or early February so that they can sprout.

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[1] The John Innes composts are made up as follows:

**SEED COMPOST**

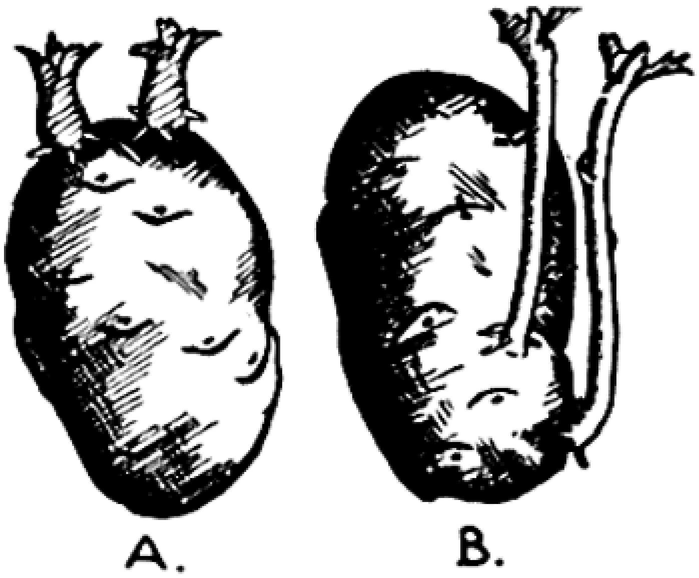
| | | |
|---|---|---|
| Parts by bulk: | + | 1½ oz. superphosphate |
| 2 Medium loam | | and |
| 1 Peat | | 1 oz. ground chalk or limestone |
| 1 Coarse sand | | per bushel (22″ × 10″ × 10″). |

**POTTING COMPOST**

| | | |
|---|---|---|
| Parts by bulk: | + | 1½ oz. hoof and horn meal |
| 7 Medium loam | | and |
| 3 Peat | | 1½ oz. superphosphate |
| 1 Coarse sand | | and |
| | | ¾ oz. sulphate of potash |
| | | and |
| | | 1 oz. ground limestone or chalk per bushel. |

N.B. The loam must be sterilized.

The boxes are then put into a light airy room that is safe from frost. This procedure is called 'boxing' and there are various reasons for doing it. In the first place the tubers get a chance to begin growing before the weather is suitably warm for planting them out of doors. This gives an *earlier crop* of potatoes. Secondly, any 'seed' that are not very healthy will fail to produce good shoots so that they can be rejected at the time of planting. This ensures a *fuller crop*. And lastly—when the time for planting arrives all but two healthy shoots are 'rubbed off' the tuber before it goes into the ground. This is said to provide, not a bigger crop but a *crop of bigger potatoes*. There will be fewer potatoes so you will be told, but those that do appear will be of a really useful size. It is easy to see the truth of the first two claims but the last *assertion* may be something of a 'fairy tale'; however, we can carry out a garden trial so as to observe the truth for ourselves. Let us carry out an experiment to test the effects of treating 'seed' potatoes in a variety of ways. We will plant groups of tubers that have been treated in each one of the following ways:



When potatoes are to be sprouted they should be placed with the 'eyebrows' *beneath* the eyes (A), otherwise long weakly sprouts may be produced (B).

**A.** 'Boxed' and left with two sprouts each.

**B.** 'Boxed' and left with all sprouts.

C. Not boxed at all, but planted from the bags in which they were delivered.

D. Not boxed, but cut in half—each half planted separately.

E. Not boxed, but cut into small pieces each of which has one 'eye' only. Each piece planted separately.

F. As for C, but all haulms as they grow removed except one.

Now for our decision about size of plot, arrangement, and quantity of potatoes. We shall need at least 12 plants of each sort in order to get reliable results, which means planting a total of 72 'seed.' These must all be of the same sort and out of the same bag. It would be wise to choose an early variety like Sharpe's Express, so that you can harvest them and check the yields before the end of the school year. Early varieties have to be planted 15 inches apart and the rows may be spaced 2 feet 6 inches apart. If we choose to put 12 potatoes in a row we shall need six rows, each of which will be about 16 feet long. A plot 18 feet by 12 feet will give you ample room and the plants round the side of the plot will be well away from the paths. We need to give this distance at the edges because plants at the edge of a plot are usually inferior to those growing further in the garden, and we wish to avoid all irregularities of this kind.

As in the cabbage experiment, choose a plot that has been evenly treated in previous years and draw a *scale* plan of the lay-out, which should be carefully copied into your Country Book. In order to scatter the variously treated tubers over the plot it will be necessary to grow two of each sort in each of the six rows. Thus, the first row will contain two each of the **A, B, C, D, E,** and **F** sorts as shown in Fig. 4. The second row will have one of the **B** sort at the top end, followed by one each of the **C, D, E, F,** and **A** sorts, and so on. This gives a very effective scatter pattern as groups of similarly treated 'seed' occur on several parts of the plot, and the effects of variations in the soil are thereby ruled out.

| *Row 1* | *Row 2* | *Row 3* | *Row 4* | *Row 5* | *Row 6* |
|---|---|---|---|---|---|
| A | B | C | D | E | F |
| B | C | D | E | F | A |
| C | D | E | F | A | B |
| D | E | F | A | B | C |
| E | F | A | B | C | D |
| F | A | B | C | D | E |
| A | B | C | D | E | F |
| B | C | D | E | F | A |
| C | D | E | F | A | B |
| D | E | F | A | B | C |
| E | F | A | B | C | D |
| F | A | B | C | D | E |

Fig. 4.

Take care to give the same cultivation treatments to all the rows. For example, each time you draw a little more soil to the ridges, tackle all the ridges on the plot. Your manurial treatment too must be very evenly made—more fertilizer in one part than another might spoil the experiment altogether: you would not be *sure* that the various crop weights were due only to the way in which you had treated the tubers. In any scientific experiment it is necessary to equalize all factors except the one that is under trial; and haphazard manuring or haphazard cultivation would introduce a variety of factors to affect the various potato plants.

At harvest time, which will be some time in July, take up all the **'A'** plants first, then all the **'B'** plants, and so on—wash the crop, weigh the tubers from each plant separately, and enter the weights in your note-book. Make a note also of the number of tubers to each plant and make a comment on their size. It is very important to avoid getting the crop from the various groups mixed up in any way. If you harvested the crop row by row you would most certainly get confused and the season's work would be spoilt. Nevertheless, the whole job should be done on the same day as 'new' potatoes are still growing rapidly in July.

Arrange the results in your Country Book in this way:

YIELDS

| Treatment | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Weight of crop | x lb. | | | | | |
| Number of tubers | *n* | | | | | |
| Size of tubers | Large | Mixed | | | | |

This tabulation should be copied near to your plan of the rows; and a list of the details of the treatments should be written alongside so that the causes of the different yields can easily be seen. When your results are complete write a careful account of the effects of the various treatments of the 'seed' tubers.

### AN EXPERIMENT WITH DAHLIAS

The purpose of this experiment is to test the effect of disbudding and pruning on the size of dahlia flowers, and it will be necessary to start the tubers[1] into growth in mid March. Put them in deep boxes or in plant pots, cover them with three inches of old potting soil, and place them in a temperature of 55° F. or thereabouts. Water them moderately from time to time, and in about six weeks when the shoots have begun to grow the tubers can be planted out in the garden. Give a covering of two inches of soil above the crowns, and if there are signs of night frost at any time, cover the ground with straw to protect the young shoots.

Your object is to discover the effects of two pruning treatments on the size of blooms:

1. Removing all but the strongest three shoots from any one plant—i.e. shoots growing from beneath the soil—and
2. Removing all but the leading flower-buds from these three main shoots and also from any lateral shoots that develop on them.

In order to make these tests the following different treatments will be necessary:

**A.** Remove neither shoots nor buds.

**B.** Remove no shoots, but remove all buds except the terminal bud on each shoot and the terminal bud on each lateral.

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[1] You must choose tubers all of the same variety of course—any early, strong-growing, formal decorative strain will do quite well.

C. Remove all but the strongest three shoots, but remove no buds.

D. Remove all but the strongest three shoots, and remove all buds except the terminal bud on these three shoots and the terminal bud on each lateral.

For a reliable test you will need 6 plants in each category—a total of 24—so that your plot needs to be 15 feet by 10 feet in order to take the plants at a distance of 2 feet 6 inches apart. This size will allow of a margin of rather more than a foot all round the plot. Scatter the plants as described for the potato trials and take care to put them all in soil that has had similar treatment for some years. The removal of the shoots must be carried out in July and the *disbudding* has to be begun in August as the buds appear, i.e. when they are quite tiny. When the plants are in full bloom the results of the various operations will be quite clear and you should enter the details in your book as you were directed to do for the previous trials. You will find that the plants in some of the sections have much bigger flowers than those in other groups.

Remember that this experiment is not intended to show that bigger flowers are more attractive! It is designed only to show the effects of certain treatments: it is not concerned with your preference for larger or smaller flowers. The horticultural race for bigger blooms or bigger crop yields often takes place at the expense of quality. For example, the best flavoured potatoes like Sharpe's Express, among the earlies, and King Edward, among the main crops, do not produce such heavy crops as some of the better 'bulkers,' as we call the heavy yielding varieties of potatoes; but their excellent quality makes them well worth growing none the less. The *discriminating* gardener pays attention to quality as well as quantity and there is much to be said for his policy. Crops and flowers are not *necessarily* better when they are big—in some cases they certainly are, but many flowers are attractive *because* of their small blooms; and most low yielding varieties of food crops are of excellent flavour.

## THINGS TO DO

(1) Write a short composition explaining *clearly* why it is necessary to use a scatter-plan when carrying out experiments with crops. Select your own title for the composition.

(2) Write single sentences in answer to the following questions:

- (*a*) What can you say about the treatment in previous years of a piece of land on which you propose to carry out a plant trial?
- (*b*) What can you say about the marking out of a garden with pegs and lines?
- (*c*) Why is it wasteful to put nitrogenous fertilizers on land that is not carrying a crop?
- (*d*) Why is it necessary to take special precautions against the failure of individual plants when carrying out crop trials?
- (*e*) What *disease* often attacks 'greens'?
- (*f*) What *pest* often attacks 'greens'?
- (*g*) Why does the 'boxing' of potatoes produce an earlier crop?
- (*h*) Why does the 'boxing' of potatoes produce a heavier crop?

(*i*) Why does the 'boxing' of potatoes produce a crop of bigger potatoes?
(*j*) What are the parts by bulk of loam, peat, and sand in the John Innes seed compost?
(*k*) What are the parts by bulk of loam, peat, and sand in the John Innes potting compost?
(*l*) Can you suggest why many modern sorts of raspberries are poorer in flavour than some of the more old-fashioned sorts?

(3) Plan out and enter into your Country Book the method you would adopt for a crop trial intended to show whether you get a heavier crop of broad beans by allowing several shoots to develop on each plant or whether you get a heavier crop by allowing only the main shoot to grow.

(4) It is said that the phosphorus in dressings of bone-meal given to chrysanthemum plants causes the production of better blooms. How would you arrange a trial to show the truth or falsehood of this opinion?

## 5

# A Place of your Own

Happy the man whose wish and care
  A few paternal acres bound,
Content to breathe his native air
            In his own ground.

Whose herds with milk, whose fields with bread,
  Whose flocks supply him with attire;
Whose trees in summer yield him shade,
            In winter fire.

ALEXANDER POPE (1688–1744).

Art thou poor, yet hast thou golden slumbers?
      O sweet content!

THOMAS DEKKER (1575–1641).

YOU WOULD probably think yourself very lucky indeed if you were able to take up farming on your own account. A farmer's life is a hard and responsible existence—there can be no five-day weeks for him—but it is a very satisfying life; and a liking for 'the soil' is part and parcel of the temperament of many British people. A fondness for the country and country ways of life has been handed on to us from our ancestors most of whom worked on the land.

As you know, the farmer needs to be a person of wide knowledge, good judgment, and industrious nature; but although his life is a hard one, it is never monotonous. He is rewarded not only by the living he makes when times are prosperous but also by the interest that comes from dealing with living things. No two days—no two years even—are ever quite alike.

Constant changes in the weather and in conditions of the market require him to be a man capable of quick decisions; and, above all, the farmer needs to be a man who will 'take a chance' because—in dealing with living things and with the uncertain British weather—he can never know exactly what the results of his work will be. Some years may bring bumper crops and good markets—he needs to be a good winner; other seasons may bring disastrous crop failures, serious stock diseases, and poor markets—he needs to be a good loser, to look always beyond the present, to take the bad with the good, and never to lose interest in his important work. Farming, you see, demands the highest qualities of character—it is not an easy life; but the job well done is full of continued interest and it is its own reward.

'The best "muck" is a farmer's boot.' So runs an old country tag; and it means that a good farmer is often in his fields so as to keep a regular check on the needs of crops and stock.

You must not forget that, without the farmer, our civilization would collapse and vanish; and there are few occupations about which this important statement can be made.

## WHAT WILL YOU PRODUCE?

No two farms, of course, are ever alike, and if you are able to take over a farm you will have to make many important decisions at the outset. What will your first decision need to be? **To begin with it will be necessary to decide what things you are going to produce for sale, because the prosperity of the farm will depend on the sales you make.** Let us think about crops first. Some of the things you grow will be *cash crops* intended for sale; others will be intended for *consumption* by farm stock. You will need to decide on the number of acres you intend to devote to these two classes of crop. And what about stock? Your decision about the crops is bound to depend on the stock you propose to keep—these two *aspects* of your farming will need to fit together like two pieces of a jig-saw; they will be interdependent.

You must not think, however, that you can choose whatever crops and stock you like. Your decisions will depend first of all on your possible markets, then on the kind of soil on your farm, and then on the local climate. In these days of Marketing Boards the selling of farm products is much easier than it used to be, but even so nobody would be able to produce large acreages of, say, sugar-beet in the north of Scotland—there is no sugar-beet factory in that part of Britain. Again, suppose your farm to have a heavy clay soil, and suppose it to be situated in the west of Britain where the annual rainfall is fairly high. What main cash crop would you grow there? What about wheat? Clay soils are rich and wheat does well on rich land. But you would not depend on wheat as a main crop in the west of Britain because wheat grows better and ripens earlier in a drier climate. The heavy land in the east of our country is more suited to wheat because of the lower rainfall. What about barley? Good barley always fetches a good price—would you be able to grow good barley? Here again your answer must be no. Barley, like wheat, prefers a drier climate for early ripening and it grows better on 'thin,' light soils. What about 'root' crops—potatoes, for example? Again you would need to reject the idea. The moist climate would be suitable certainly, but potatoes would be very difficult to harvest from heavy land—and in any case they grow best in a light, sandy soil. It begins to look as though you would not be able to grow any of the popular cash crops very successfully. The very best crops for heavy land in a wet climate are such things as grass, oats, kale, and mangolds—all of which are important cattle foods. Now you can make your decision—your main source of income would have to come not from crops but from milk and live-stock; your farm would be destined for dairy work and your crops would be intended mainly for cattle fodder—not for cash.

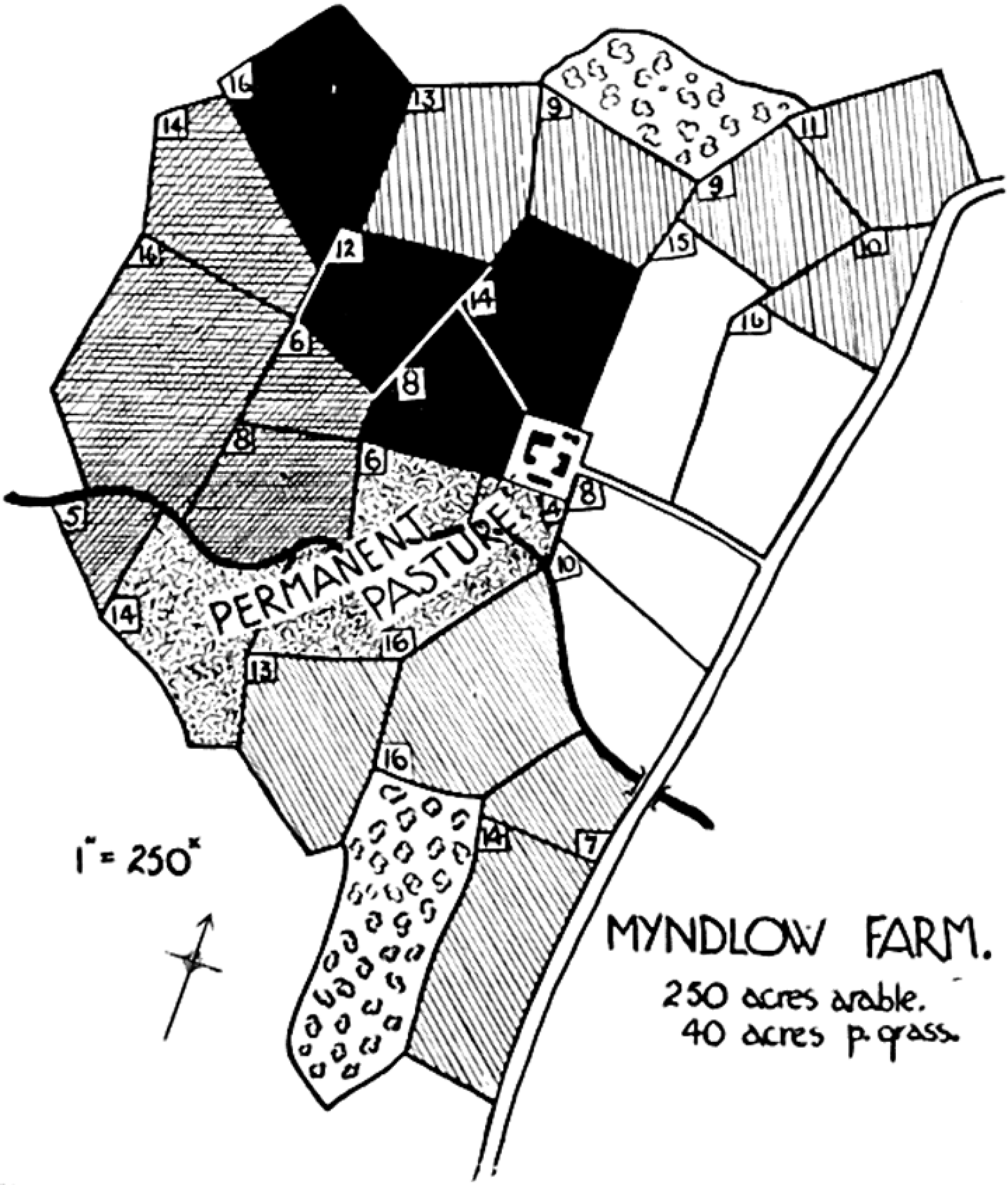
No matter where your farm was situated, the crops and stock that you produced would be decided in much the same way. The fact that most of our best dairy land is in the west and most of our best wheat and barley is grown in the east is not just a matter of the personal preferences of British farmers—climate and soil have decided these things for us. Now let us have a look at an actual farm in the east of England and see for ourselves how the crops and stock depend on one another, on the soil, and on the climate.

## A LIGHT-LAND FARM IN WEST NORFOLK

The accompanying plan gives you a clear picture of the lay-out of the fields. There are 290 acres of useful land, together with about 20 acres of open woodland, and a small stream runs through the middle of the farm. The fields are compactly arranged—not dispersed over a straggling area—so that there is no need to travel long distances to the boundary fields, and the farm premises are centrally placed with a private road leading to the public highway. The lay-out could not be better as no time is lost in getting about the land with implements and stock; and the highway running nearby makes the farmer's contact with the 'outside world' quite easy.

The farm premises are both picturesque and well arranged. The small old house is thatched and it flanks the square farmyard around which the farm buildings are arranged; there is a big corn barn that was built in the days when threshing was done with a flail, and this fine old building makes an excellent store-shed. Alongside the corn barn is a granary with a grinding-barn below it; and round the remainder of the yard is a series of four covered bullock-yards (where bullocks can be kept and fattened during the winter), some loose-boxes, a cart-shed, and an implement shed. A deep well at the homestead provides plenty of clean water for stock and for domestic use.

What of soil and climate? If you intend to farm this very desirable holding you will need, remember, to consider these two factors very carefully before



Here is your farm. What crops will you grow, and what stock will you keep? Notice that the arable fields are shaded in five different ways—why is this? (*The figures indicate the acreages of the fields.*)

deciding on the crops and stock you intend to produce. West Norfolk is in one of the driest parts in Britain with an average annual rainfall of under 24 inches and the summer months are the driest. You will already have said to yourself: 'I shall certainly grow grain of some kind as a cash crop because grain ripens best in a dry warm summer.' The particular sort of corn you choose will depend on the soil. If the soil is heavy, wheat will be best; if light, barley. And barley is likely to be your choice, for all the fields of this farm have a light sandy soil that overlies a loose gravel, so that there is never any difficulty with drainage. This loose, well-drained soil warms early in the year, it is easy to work, and it will carry heavy tackle in the early spring so that there is never any difficulty in getting an early seed-bed. Most barley as you know is sown in spring, not autumn, so that it is important for barley land to be 'early' land in order that sowing can take place in March at the latest.

If there is much barley grown in your district, you may be sure that the soil is free-draining and warms up early in spring.

You will not be surprised to learn that the present farmer of this land grows 110 acres of barley each year; and as he frequently gets 24 cwt. of grain per acre, he is able to sell about 100 tons of barley each year in addition to keeping some back for stock food.

Now for some further decisions. First of all, will there be any other cash crops? There are still about

180 acres of land to be considered. What do you think? What about some potatoes or some sugar-beet? Light land will grow both of these very well indeed provided it is well manured. You could grow either, but this farmer grows 40 acres of sugar-beet because he is close to a sugar-beet factory and he has no difficulty in selling the crop. Furthermore sugar-beet, unlike potatoes, produces some stock food as well as producing a cash return on the sugar: sugar-beet tops are used as stock food and are as nourishing, weight for weight, as swedes. In addition, the dried sugar-beet pulp that comes back from the factory has almost the same feeding value, for dairy cows or fattening bullocks, as ground oats!

Before choosing any more crops for the remaining 140 acres, you will need to decide whether or not to keep stock of any kind, because if you do it may be necessary to grow some crops especially for them.

## THE CHOICE OF STOCK

You will certainly need to carry stock of some kind on this farm. Can you give a good reason? It is true that you already have some stock food from the sugar-beet which it would be unwise to waste; but there is a much more practical reason than this. What is it? Remember what you learnt about the American 'dust-bowl' in the chapter on soil fertility. It was lack of humus and other plant foods that caused that disaster. The lighter and more sandy a soil is, the greater is its need for humus and **you will need to carry enough stock to produce a sufficiency of farmyard manure.**

Even though your labour with the stock might provide no profitable cash return, you will none the less need to keep farm animals in order to turn as much of the straw as possible into manure so that the land can be kept fertile for growing your two cash crops—barley and sugar-beet. For this reason, the owner of this farm keeps thirty winter bullocks that he fattens for the beef market. Very often he has to sell them at a loss because, of course, he needs to buy expensive protein concentrate cakes for them, and they take up a great deal of his time. But they are indispensable: the manure that is made in the covered yards where these bullocks spend the winter is the very corner-stone of the farm's fertility. 'No horn, no corn' is an old country saying—a way of stating the need for farmyard manure. The farmer buys these bullocks as store cattle (that is, cattle that are fully grown but not fattened) in October or early November each year and they go off fat four or five months later. When brought in they weigh on the average 7 cwt. each and when they go off they have fattened to 11 cwt.—a total of 6 tons of extra 'beef'! Remember, however, that the manure is much more important than the beef to this farmer. He keeps the bullocks in order to convert his abundant straw into good manure. A further batch of thirty similar cattle is bought at the end of the winter for fattening on the pastures during the summer but these, of course, drop their dung on the turf that they graze.

In addition to these cattle, 200 lambs are bought at the lamb sales in October or November each year. These also are kept because of the manure they make, but unlike the bullocks, the lambs do sell at a price that pays not only for their food but also for the cost of looking after them. You may wonder why bullocks are kept at all if extra numbers of profitable lambs could be used to provide all the dung. The difference of course is that the bullocks can be kept in the covered yards where they are able to 'tread' daily beddings of straw into their dung in order to produce the farmyard manure. Sheep, however, can be kept in the open right through the winter and their droppings enrich the soil on which they are folded; but they do not make farmyard manure—straw is an essential ingredient of that: so the winter bullocks are essential. The lambs are about seven or eight months old when they are bought each autumn and they are kept until the following March when they are about a year old. At that age they are sold off as fat lambs.

These Devon bullocks are being wintered in a yard that is only partly covered. Why is so much straw used for their bedding?

## CROPS FOR THE STOCK

All this stock will need providing with food; and it will be necessary to grow as much as possible of this in order to save the expense of buying it. Some protein concentrate will have to be bought for the cattle and for any pigs that are kept, but apart from that everything can be grown on the farm. To begin with you will need to have some permanent pasture to carry the summer bullocks. You can reckon about an acre or so of grass to each bullock, so that 40 acres would be ample; but it would be unwise to have much less otherwise the stock would overgraze it. Overgrazing and undergrazing are equally bad for grassland—both of these extremes of grazing cause the pasture to deteriorate because of the appearance either of abundant weeds or of rough grasses that are not nourishing. However, the herbage of 40 acres can be kept in tip-top condition by the thirty bullocks carried on this farm during the spring and summer.

There is, of course, no hay taken from this permanent grass as the cattle keep it closely grazed; but hay will be necessary for the winter bullocks in the covered yards. What would you do about that? You would need to grow some seeds-hay in your arable rotation, and that is what happens on these fields. The farmer sows a mixture of broad red clover and Italian rye grass on one 'break' of the land each year. How many acres of 'seeds' will be necessary? Let us work this out.

The daily fattening ration given to each bullock while the cattle are in the yards consists of 5 or 6 lb. of bought protein concentrates, together with 8 lb. of sugar-beet pulp and 8 lb. of hay. Thus, the thirty bullocks need altogether about 16–20 tons of hay during the winter, and in order to be sure of this quantity and to have enough for his horses and his fattening lambs the farmer sows 50 acres of seeds-hay each year. His average yield is about 1½ tons per acre; and in a good year there would be enough surplus to keep in case of a partial failure of the crop in the following year.[1]

We have now 'ear-marked' 240 of the 290 acres so that there are still 50 acres for which we have not planned. What about the main food supply for the fattening lambs? They can graze the aftermath of the seeds-hay during the autumn, and after that they can go on to the fields from which the sugar-beet is being harvested where they can graze the wilted[2] tops until the end of December. From January onwards they will need to be provided with food that is specially grown for them. What could you grow for lambs *to eat in the fields* between January and March? The popular crops for them at this time are swedes and kale. The lambs can be folded on these crops: that is to say they can be enclosed by a portable hurdle-fence which is moved further into the field as the crops are eaten up. In this way the 'roots' are completely consumed, each part of the land is enriched with droppings, and the sandy soil, which has probably been 'lifted' by the winter frosts, is made firm again. This is a very good thing because barley grows best in a firm soil and the constant treading of a flock of sheep 'brings the land together,' as the farmer puts it, much better than the heaviest roller. The whole of the 'root' break—sugar-beet and kale or swedes—will be trodden each year by the lambs in this way. Ten acres of roots, however, will be ample for 200 lambs and you have still 40 acres to 'play with.'

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[1] You should check these calculations in the arithmetic period.

[2] Sheep should not eat sugar-beet tops until they are wilted—can you find out why?

The main *enterprise* of the farm would run quite well without these 40 acres so you can please yourself what you do with them. They would produce enough grain—wheat and oats—to feed about 1,000 poultry provided some concentrate balancer meal was bought in addition. Let us suppose you decide to do that—there will be a reasonable profit from eggs produced in this way and your open woodland will allow you to run the birds on the open-range system so that you would be unlikely to have frequent danger of disease or sickness among the flock.

### ARRANGING THE ROTATION

Having decided on the crops and the stock that your 290 acres of land is to carry, it will be necessary to arrange a fixed rotation of cropping—and you will find that the crops you have chosen more or less fix the rotation for you. Let us list the crops that are to be grown on the arable land—you are to have 40 acres of permanent pasture grass which leaves 250 acres for the plough.

### Arable Crops to be Grown

| | |
|---|---|
| **Grain** (110 acres of barley and 40 acres of wheat and oats) . . . . . | **150 acres** |
| **Roots** (40 acres of sugar-beet and 10 acres of kale or swedes) . . . . . | **50 acres** |
| **'Seeds'** . . . . . . | **50 acres** |

These quantities will enable you to divide the arable fields of your farm into five 'breaks' of 50 acres each and you will be able to arrange a five-year rotation with three crops of grain grown alternately with a crop of roots and a crop of seeds. This is a most desirable sequence. Do you remember the reasons for crop rotation that you learnt in Book I, Chapter 8? In that chapter—called 'Change-about Farming'—you were told that the rotation of crops enables the farmer to control pests and weeds more easily, and that it enables him to distribute his farmyard manure more evenly round his fields. If you have forgotten any of the reasons for these advantages of rotating the crops you should read that chapter again to refresh your memory.

A further advantage of crop rotation has to do with the exact *sequence* of cropping. In making the plan for the farm you will need to consider the order in which the five 'breaks' are to be grown. There will be 50 acres each of roots and 'seeds,' together with three 50-acre breaks of corn. Let us write them down in that order to begin with:

Roots
'Seeds'
Corn
Corn
Corn

Suppose you decide first of all what is to come after the roots? Remember what happens to all those root-crop fields—they are folded and trodden by the lambs. Does this help you to decide which crop shall follow? The best answer is . . . barley: the firm treading of the sheep ensures an excellent seed-bed for a good barley crop. Your sequence of cropping, you see, is beginning to decide itself. What will you put in after the barley? If you sow your 'seeds' just after the barley has begun to grow you will be wise. Can you think why? The young grass and clover of the 'seeds' will be able to commence their growth while the barley crop is developing and ripening so that after the barley is harvested in the summer, the 'seeds' crop will already be well established. The 'seeds' break occupies the ground for well over a year, and if you didn't grow barley as a nurse crop over the 'seeds' in the first spring and summer, you would lose that corn crop altogether. The land would be idle while the seeds got going; but by arranging your order of cropping so that the seeds follow the barley, you are enabled to take a whole extra break of corn. This is another very real advantage of a rotation. Nor is this the only benefit you will get from growing your seeds at this stage; any crop of corn takes a good deal of plant food from the soil—we say that corn crops are *exhausting*—but 'seeds' leys that contain clover restore some of the lost fertility. The masses of grass

A crop of barley often has a crop of 'seeds'—clover and grass—growing beneath it.

and clover roots turn to humus when they die and the clover adds a good deal of nitrogen to the soil as you know. The land will be in good heart again after the seeds; and ready to take the two breaks of corn that remain to be included in the rotation. The order of cropping therefore will need to be:

| | | |
|---|---|---|
| **Roots** | | 50 acres |
| **Barley** | | 50 acres |
| **'Seeds'** | | 50 acres |
| **Mixed corn** | (Spring wheat: 20 acres<br>Spring oats: 20 acres<br>Spring barley: 10 acres) | 50 acres |
| **Barley** | | 50 acres |

After the barley in the fifth year, you will begin all over again with the roots; and of course the heavy dressings of farmyard manure and chemical fertilizers that you will give to the root break are needed by the soil after the two years of exhaustive corn cropping.

The rotation you have chosen is very similar to the rotation that has been used on this particular farm for over two hundred years—it is indeed the old original Norfolk four-course rotation [1] with one break of corn added to it—and the land is as fertile to-day as it ever was. This is due largely to the importance the farmer attaches to farmyard manure and to sheep droppings. The bullocks take no fertility off the land when they are sold—indeed they bring fertility in because their skeletons are fully grown when they arrive and their dung and urine are exceptionally rich in plant foods because of the rich cattle cakes that are bought for their rations. During the five or six months that they are on the farm they are consuming these rich foods at the rate of over a hundredweight a day—altogether they consume some 15 tons of bought cake before they are sold off, and the rich dung that this ensures is a valuable source of fertility to the farm. Indeed the only mineral fertilizers that are used on this farm are given to the 50 acres of roots and the 20 acres of spring oats. The remaining 180 acres of arable crops receive no bag manure at all. The small amount that is bought is necessary in order to balance the fertility that is sold off in the fat lambs, the eggs, and the poultry. The main fertility drain, which is due to the sale of barley and sugar-beet, is balanced by the bullock manure rich from the purchased concentrates.

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[1] See *Rural Studies*, Book I, Chapter 8, if you wish to refresh your memory about the Norfolk four-course rotation.

## PLANNING THE ARABLE LAND

Everything is now ready for you to begin making your cropping plans for the first year. It is usual to take over a farm well before the autumn so that plans can be drawn up, seed orders placed, and so forth before the autumn cultivations begin. Turn again to the plan of the farm on page 93. It will be as well for you to make a careful tracing of this in your Country Book so that you can mark your proposed lay-out on it. You will need first of all to decide where you are going to have your 40 acres of permanent grass. The plan shows clearly where the present farmer has placed his pasture fields. Can you explain the choice? Those grass fields are going to be stocked by bullocks in the thirsty summer months. There is only one place for them. Since there is no piped water on the farm, the permanent grass *must* go alongside the brook. Choose several fields along the brookside that total about 40 acres in area and mark them off for that purpose. It would be a good idea to give them a wash of very pale green paint and to label each field: *Pasture.*

The remaining 250 acres will have to be divided up into five breaks—each of which is as near to 50 acres in area as possible. Will you have the crops in your various breaks growing in *adjacent* fields or will you have them scattered about the farm? The roots, for example—will you have these scattered in various fields about the farm or will you arrange to have them in a neat block all close together? Since your soil is similar all over the farm and since all of it is quite suitable for growing roots it would be much better to arrange to grow your 50 acres of sugar-beet, swedes, and kale in a group of fields that are close together. Can you think why? By doing so you will avoid the need to move your implements all over the farm whenever you are attending to root cultivations. If you had to move your ploughs, hoes, seed-drill, harvesting implements, and so on from one end of the place to the other every time you were dealing with the root crops you and your men would waste a good deal of time. So divide the arable land up into five compact *parcels* of adjacent fields. It does not matter what size the fields are so long as those in each break or parcel have a total area of about 50 acres. When you have done this you can allocate one crop of your rotation to each break. At the end of five years the roots will have been grown on every field on the farm; and the same is true of all the other crops so that it makes no difference which break you choose for the roots and so forth in the first year. What does matter is that you must take care to make a complete change of crops on each break every year—in the exact order of the rotation that you have chosen; and you must make the same change in all the fields of each break. Otherwise you will lose track of your rotation altogether and you will get into a hopeless tangle. On your diagram use colour washes of different tints to indicate the five breaks, label all the fields in each break with the name of the crop it is to receive this year, and your planning is complete.

You will have realized by now that a great amount of careful thought is necessary for successful farming—a great amount of hard work too. In spite of all this detailed planning things can go wrong—the weather can ruin the corn harvest, a long winter can keep you off the land when you need to get on to it in the spring, disease can be brought into your stock from other farms, and so on; these are things you cannot regulate. But by and large 'there is a seed time and a harvest' as we say in the country and if things are bad in one year they frequently right themselves in the following season. Thoughtful farmers do, however, try to guard themselves against complete loss in any one year. Notice that there are two cash crops on this farm—barley and sugar-beet. In an exceptionally wet season the barley may fail but the sugar-beet will do well—whereas in a moderately dry season the sugar-beet may yield poorly but the barley will probably give a bumper crop. You noticed also that the 'seeds' break would normally produce rather more hay than the stock could eat. This arrangement may enable the farmer to save some hay against a bad season in the following year. This extra fodder is a kind of insurance against future shortage, and if ever there is too great a surplus it can easily be sold to provide an additional source of revenue.

## FARMERS' WAYS ON WORKING DAYS

One of the best ways of enjoying a holiday is to watch other people at work!—so let us take a walk round the buildings of this Norfolk farm on a morning in spring when surface cultivations (harrowing, rolling, seed-sowing, and suchlike) are demanding every minute of the men's available time. Land workers very rightly take a great pride in their labours, and most of their tasks demand not only knowledge but also a great deal of skill—skill that comes from long experience. There is a right way and a wrong way of doing most jobs; and in dealing with living material, mistakes and bungling can often lead to disaster. It is probable too that no other occupation requires such a wide range of skills as farming—and every man on the place needs to be able to give a hand with all sorts of work. On a big farm, of course, numbers of the men are specialists—there may be a horsekeeper, a shepherd, a cowman, a pigman, and so forth, depending on the size of the farm and the particular crops or stock that have to be dealt with. But the general farm worker needs to be able to tackle any job that is going. He has to be very *versatile* indeed.

### PREPARING THE HORSES FOR FIELD WORK

If you arrive early enough you will be able to see the horses being got ready for their day's work on the fields. There is only one tractor on this 290-acre farm but there are four working horses. You may wonder why so many horses are still kept in these days of farm mechanization; but there is a very good reason. There are, you will remember, 250 acres of arable land so that there is plenty of work for the implements to cope with. All the fields are fairly small, however,

The horsekeeper was busy in the stable long before these two energetic Shires began their morning task. Can you say exactly what he was doing? Why do horses wear collars?

and numerous separate fields have to be prepared for sowing grain each year. The farmer has found that he can get the job done more quickly with several horses working at the same time in different fields than he can by taking the single tractor from field to field in turn. Several tractors would of course do the jobs more rapidly, but the overhead cost of a number of tractors is too great for most farms of small or medium acreage. Speed of cultivation is very important in these islands because of the sudden and frequent changes in weather—and on this farm it is possible to do the jobs quite economically and at a good speed by using several horses in addition to the tractor. The light sandy soil is a great help in this connection of course, because some of the implements can be pulled by a single horse.

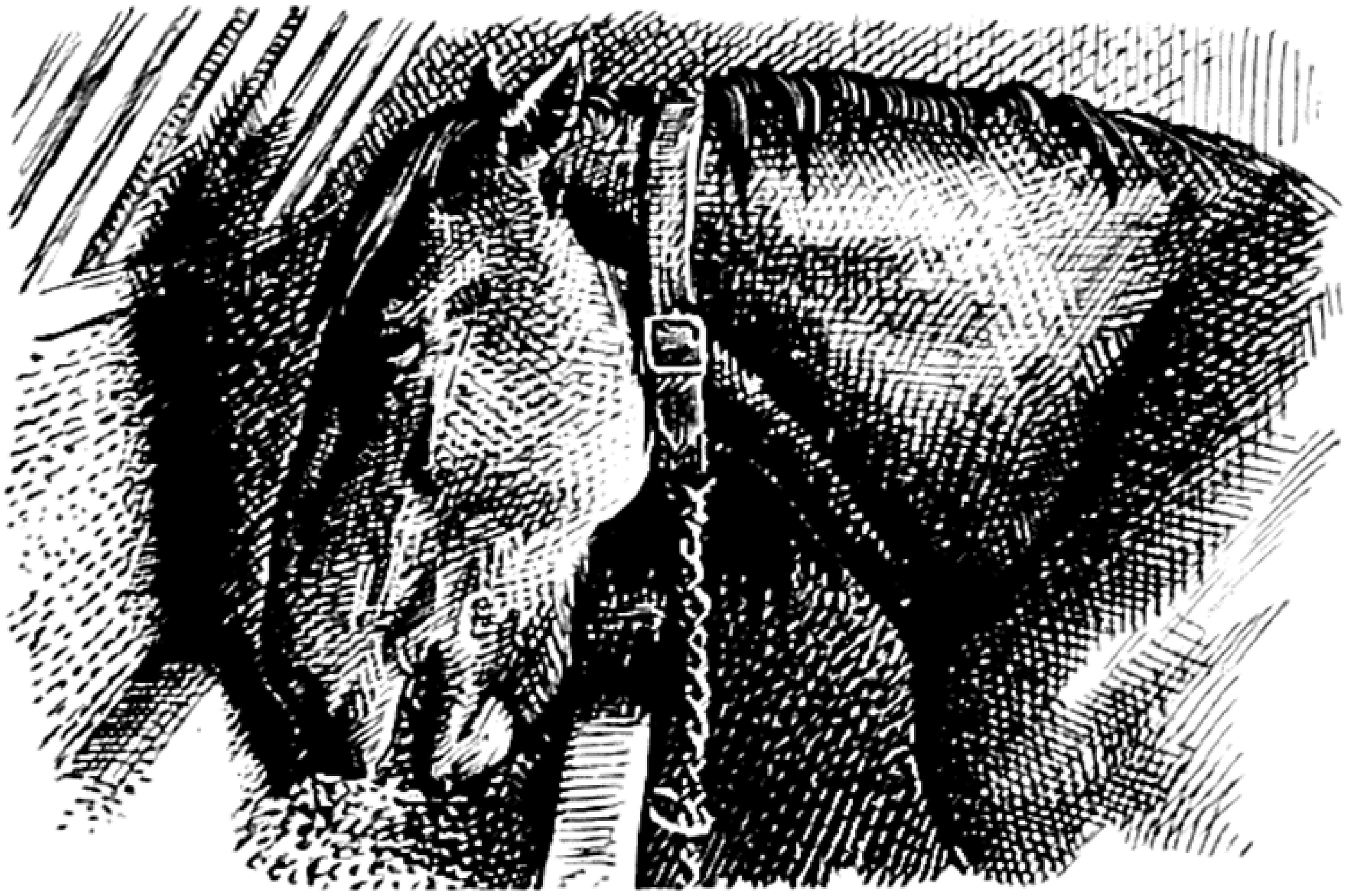
## INSIDE THE STABLE

There are four stalls in the stable so that all four horses are housed together. The horseman's first job in the day is to water and feed his charges; and he has to begin this task at seven o'clock or even earlier, as the horses need a full hour for their meal. Which would you give them first—the food or the water? The horseman will tell you that you must never give water to horses immediately after a meal—if you do you will upset their digestion. Cows can and do drink at any time—frequently even during their meals; but the horse, as you know, has no paunch and it is unable to deal with large quantities of water and food at the same time. Water given on top of a meal dilutes the digestive juices and hinders proper digestion; but if it is given on an empty stomach it passes quickly into the intestines and the food that follows is not affected by it in any way. At its morning draught a horse drinks from two to three gallons of water (it needs about ten gallons in the course of a day), and you can well understand that all this liquid needs to be got out of the way of the food.

This horse is being watered before returning to its evening meal. Why must the water be given *before* the food?

The amount of food in the ration depends on the amount of work the horse has to do—it is important to provide as much food as is necessary but it is very important not to overfeed; the overfeeding of horses that are 'idle,' especially the overfeeding of corn, gives rise to many ailments: digestive upsets, 'thick leg,' and so on. The common food-stuffs given to horses are oats and hay. Other grain can be given in addition—maybe some maize, maybe some beans; and the hay can be supplemented by some other rough fodder such as straw, chaff, or bran. But **the bulk of the horse's**

**ration always consists of oats and hay.** When on full work a mature horse needs the equivalent of 15 lb. of oats and 21 lb. of hay each day; and you will find that the horseman has provided his animals with a morning feed made up of a mixture of these two foods—5 lb. or so of oats and about 7 lb. of hay to each horse. The oats are crushed in a **roller mill** to prevent the *bolting* of the grain, and about a quarter of the hay ration is mixed with the oats after being chopped into short lengths—half an inch or so long—in a machine called a **chaff-cutter.** After the oats and 'chop' have been eaten, the rest of the hay is fed as long fodder. There is no way—fortunately!—of hurrying the horses over their meal so that you will have plenty of time to watch them busily occupied at their mangers. Most people

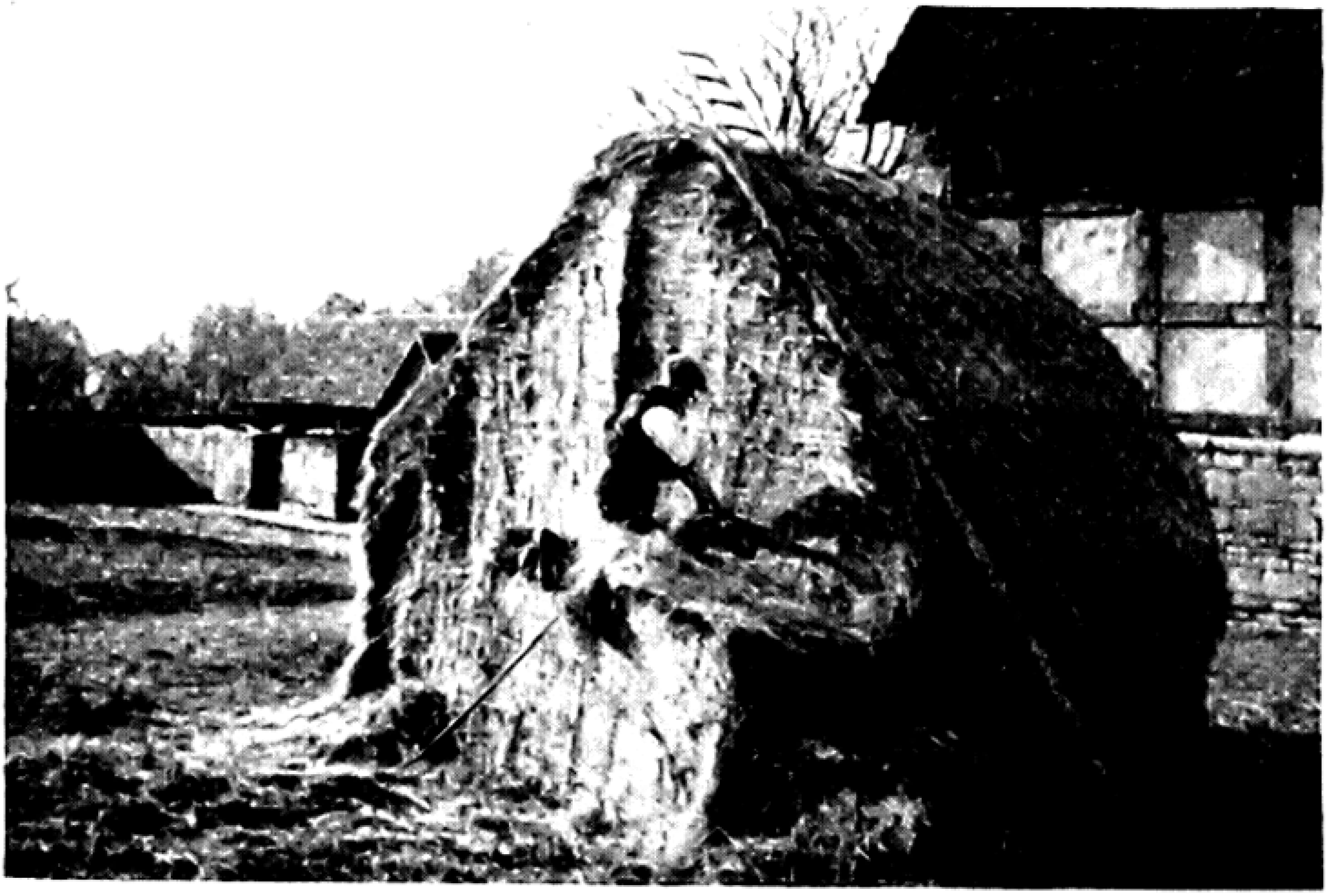


This farm horse is at his morning meal before work in the fields. What is he eating and how much of it does he need? Notice the hay rack.

enjoy the quiet companionship of horses and the comfortable smell of the buildings in which they are kept.

### THE FARMER CHECKS UP

When the men have been got away to the fields the farmer might perhaps go round the buildings to make a check of his remaining food supplies. Large quantities of the fodders and grain that he stored for use during the winter and early spring have by now been fed to the live-stock, and it is necessary for him to check the amounts that are left in order to avoid running short. He *may* need to buy in some extra hay in order to tide him over until the flush of new spring grass is ready for the bullocks and sheep; and if additional grain is necessary now is the time to make sure of getting it. He



How does the farmer calculate the *weight* of hay remaining in his stacks?

knows just how much his animals will require in their rations during the months to come; and if his cropping plans for last year were well made, he will find that his remaining stores are just about *adequate* for his needs. There should be neither shortage nor waste.

On a mixed farm home-grown grain is a most important stock food. At what time of the year does the farmer need to keep a close check on his remaining supplies?

If you accompany him to the stack-yard you will see that he is able to make a *close approximation* of the weights of hay and straw left in the stacks. He does no actual weighing of course, but he makes careful estimations of the volumes of fodder; and these volumes can easily be converted to weights by simple calculations. An example will make the method quite clear. At this time of the year the hay in the stacks is very compact because it has been standing so long—a good nine months; indeed you can see from the cut surface of one of the stacks that it is well settled and it slices almost like plug tobacco. Hay in this condition weighs about a ton to every eight cubic yards so that it really is quite easy to determine the weight of hay in the stacks once you know the volume. In the same way the farmer is able to gauge the weights of his remaining grain, farmyard manure, and so on—he knows the *conversion* figures for the different materials, and all he needs to find out is the approximate volumes of his various supplies.

As you go about the country and talk with farmers you should try to look behind the scenes as you have had to do in this chapter. Out of the hundreds of thousands of farms in Britain no two are alike and no two farmers go about their work in exactly the same way, so that there is much that you can discuss and discover. And if one day your ambition to become a farmer materializes—as it will if you really want it to—your investigations will be of untold value to you.

## THINGS TO DO

(1) For this exercise you will need several traced copies (on smooth paper) of the 6-inch map that shows the farms and fields in your district. Select a farm that you know well and mark its boundaries on three copies of the map.

Explain to the farmer that you have been studying crop rotation and ask him if he will allow you to make a copy of the cropping plans of his farm over a three-year period—last year, this year, and for the coming year. Use thin water-colour washes to show the different breaks and the permanent grass; and label the fields *neatly* with the names of the appropriate crops. When complete, the plans should be titled with the name of the farm and the date of the year of the rotation in each case. Mount the completed survey in your Country Book.

(2) Describe the rotation carefully and say which crops are grown for cash and which crops are grown for stock food. State the numbers of each kind of stock kept and give a list of (*a*) the foods that are brought in for them and (*b*) the fertilizers that are bought in to balance the fertility that is carried off the farm in crops, milk, or stock that are sold.

(3) If you were farming the land yourself you would probably make certain changes—not because they would necessarily be improvements but because no two farmers work their land in exactly the same way. Write a short essay saying what changes you might make and why.

(4) In this exercise you are required to make a list of quantities and prices in order to help you to realize the large amount of materials that your farmer handles. Find out:

(*a*) The total yield from each of the crops he grew last year. Don't forget to include the straw if there was any. [N.B. For accounting purposes the farming year runs from 4th June to 4th June.]

(*b*) The total weight of farmyard manure made in the cowsheds and yards.

(*c*) The total weight of each kind of bought fertilizer that was actually used on the fields during the year. In a third column put down the cost of each, and at the end of the list write down the total cost of the bag fertilizers used.

(*d*) The total weight of each crop sold off during the last farming year, together with the price obtained for it.

(*e*) The total amount of the various food-stuffs used during the year for any one class of stock on the farm.

(*f*) The total weight of various stock foods brought on to the farm during the year with the cost of each. Write down the total cost of all food-stuffs bought in.

(*g*) The total amount of hay stacked last summer for use in the recent winter, and the total amount the farmer hopes to stack in the coming summer. If there is a great difference try to explain it.

(5) Write a composition entitled 'The Sort of Farm I should like to Own.' Give some details of size, soil, climate, crops, stock, etc., and give some reasons for your preferences and decisions.

[*Note to the teacher:* City, suburban, and village schools wishing to make first-hand contact with a farm may do so—for a payment of 5*s*.—through the Association of Agriculture, 238–40 Abbey House, Victoria St., S.W.1. Maps, plans, photographs, and progress reports from the chosen farm are provided.]

## 6

# 'Like Father—Like Son'?

> This happy breed of men, this little world,
> This precious stone set in the silver sea
> . . . this England.
>
> *Richard II* (SHAKESPEARE).

THE LIVING creatures with which you are most familiar are, of course, human beings; and you are probably so well acquainted with all of your friends and relations that you have no difficulty at all in distinguishing them one from another. In order to do this, you have to take note of such things as differences in the colour of their hair or eyes, their manner of walking, their ways of doing things, and so on; but these after all are minor distinctions, and the resemblances between one human being and another are really very much more obvious than the differences. We all possess the main characteristics of the human *species* to which we belong and—in spite of the many small differences that enable us to recognize one another—it is very unlikely that we should ever be confused with any other form of life! These human characteristics—ability to walk on two legs, comparatively hairless skin, sense of humour, and capacity to laugh, etc.—have been handed on to us by our parents—and we, in turn, shall pass them on to our children. The same is true of all living things; in the normal course of events the offspring of all plants and all animals bear the characteristic features of the species to which they belong. When the farmer drills three or four bushels of wheat grain per acre, he quite rightly expects a good crop of wheat—not of oats or barley; and when our fireside cat has kittens we quite rightly expect these kittens to grow up into cats. Nature usually ensures that this shall be so by avoiding cross-breeding between species that are not closely related—cats breed only with cats as a general rule, sheep with sheep, apple-trees with apple-trees, dogs with dogs, and so on; it is true that there are some notable exceptions to this general rule, but they are quite unusual and more will be said about them later in this chapter.

Young kittens quite naturally grow up into cats! A moment after this picture was taken these two mischievous teasers got a sudden cuff from their peaceful mother. Just a warning!

## VEGETATIVE REPRODUCTION

You know that the gardener often 'starts a new plant' by taking a portion of shoot from a fully grown plant and inserting this 'cutting' in suitable soil.

The new plants into which these carnation 'cuttings' will grow are not true offspring of the 'parent' plant. Can you say why?

New black-currant bushes, gooseberry bushes, geraniums, dahlia plants, and so on can be produced in this way; and sometimes the cut portions of a plant root or of an underground stem can be used to produce a new plant in the same way. You will remember that this *vegetative* method of propagation is used for growing a crop of potatoes; each potato 'seed' is a portion of underground stem (a tuber) taken from an old potato plant. Very many perennial plants can be propagated by vegetative means, but it is important for you to notice that the new plant is not in any sense a descendant of the original plant. It belongs to the same *generation* as the mature plant of which it was once a part, and after being broken off it began an independent life of its own without going through any seed or 'infant' stage at all. A plant that has been produced in this way is in all respects identical with the single plant from which it came. But when living things produce young offspring—genuine descendants—by breeding, the new creatures or new plants very often have two parents and they show some resemblance to both. For instance, if a red Shorthorn bull is successfully mated with a white Shorthorn cow, the resulting calf will resemble both its parents as regards its shape, size, and so on, and it will have a coat that is partly red and partly white—indeed it will probably be what we call a *roan* Shorthorn; the red colour comes from the father and the white colour comes from the mother. Let us inquire further into the way in which mating and breeding take place. How do new young plants and new young animals come into existence?

## HOW DO LIVING THINGS BREED?

In all cases the offspring of living things are quite small when we first see them—much smaller than their parents. This is true of the tiny plant inside each seed (compare the acorn with the mighty oak)—it is true of the chicks and nestlings that come from birds' eggs, of the foal to which the mare gives birth, of the vixen's woolly cub, of the human mother's baby, and so on: all are very small indeed when we compare them with their parents. Were they ever smaller still? What were they like at the very moment of their origin? How exactly did their separate lives begin—and when? The answers to these questions will surprise you and give you cause for wonder. When a *young plant or a young animal first begins its life it is in most cases so tiny that you would need a powerful microscope in order to see it.* Even in the case of the bigger animals this **embryo**, as we call it, is minute: in the earliest stages of its growth the embryo of a calf, for example, or the embryo of the human baby, is no bigger than a pin-head!

At the moment when their lives began these lively young cubs were no bigger than a pin-head! The dog fox is off to fetch a meal!

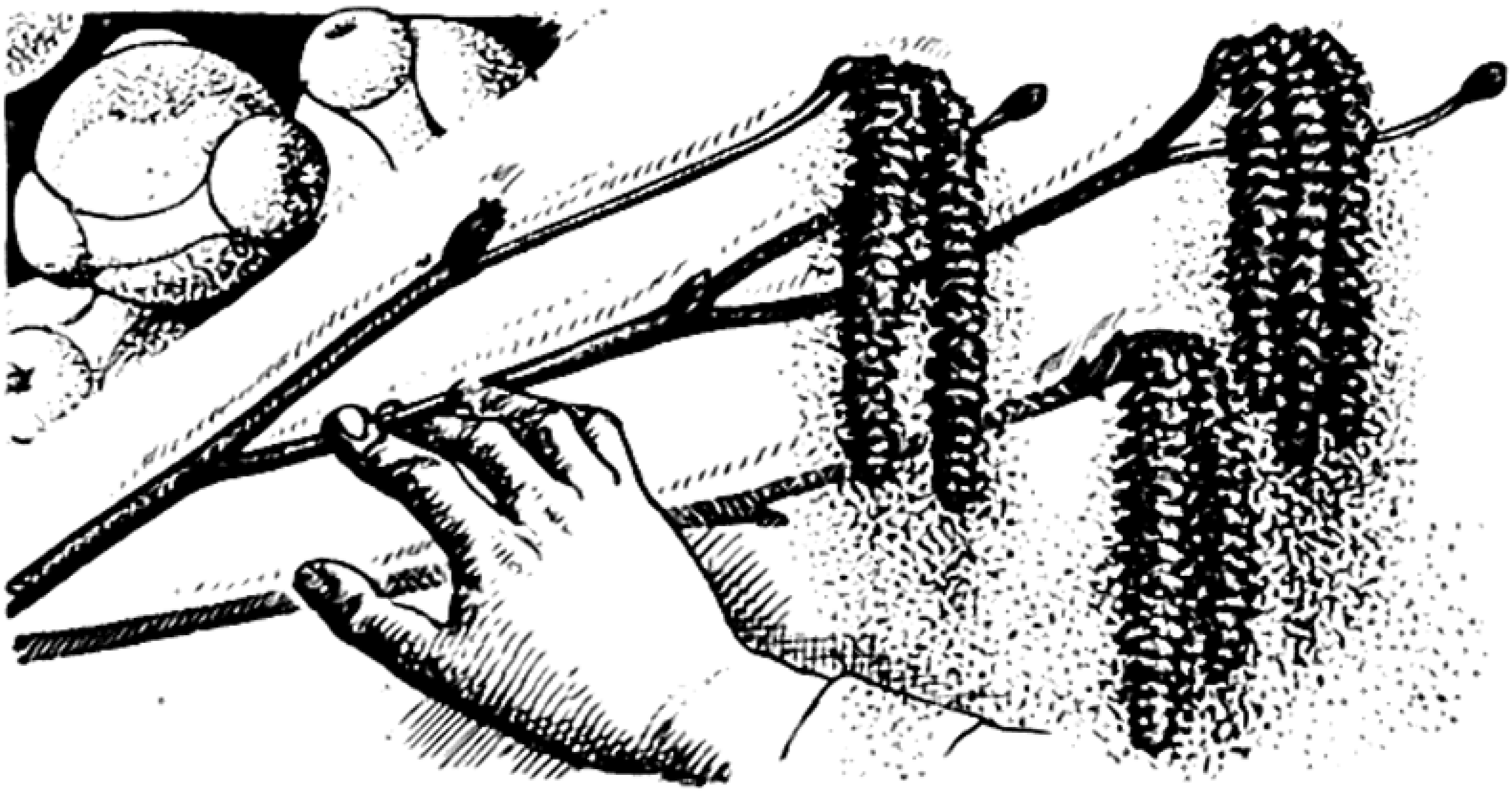
With relatively few exceptions to the rule, this tiny speck of new life is brought into being by the union of two cells—one male cell and one female cell. You have already learnt that plants are made up entirely of cells, and in much the same way the bodies of animals are composed of millions of living cells. The male and the female cells that unite to form an embryo are, of course, specially made for the purpose of *reproduction* and we call them *reproductive* or *reproductory* cells.

Whenever a new plant or a new animal is produced by the union of two cells in this way, we say that the process of *sexual* reproduction has taken place. In the case of farm animals—indeed in the case of all the mammals, birds, fish, reptiles, and the large insects with which you are familiar—these male and female reproductory cells are produced by separate individuals. Animals that produce male cells are called male animals and those that produce female cells are called female animals. This is true also of numerous flowering plants: holly-trees, for example, are as a rule either male or female and, of course, only the female tree ever bears the familiar red holly berries—the male tree produces male cells only—never the seed-bearing berries. The same is true of most kinds of willow-tree; but the majority of flowering plants produce both male and female reproductory cells *on one plant*. In such cases, genuine offspring—new young 'infant' plants—may well be produced by a single parent plant. Although the seeds of such plants have only the one parent you must take care not to confuse this kind of reproduction with the vegetative reproduction you were reading about on page 119.

The offspring of sexual reproduction belong to a new generation; but the offspring of vegetative reproduction belong to the same generation as the plant from which they were severed. Let us inquire more closely into the sexual reproduction of flowering plants.

## THE REPRODUCTORY CELLS OF FLOWERING PLANTS

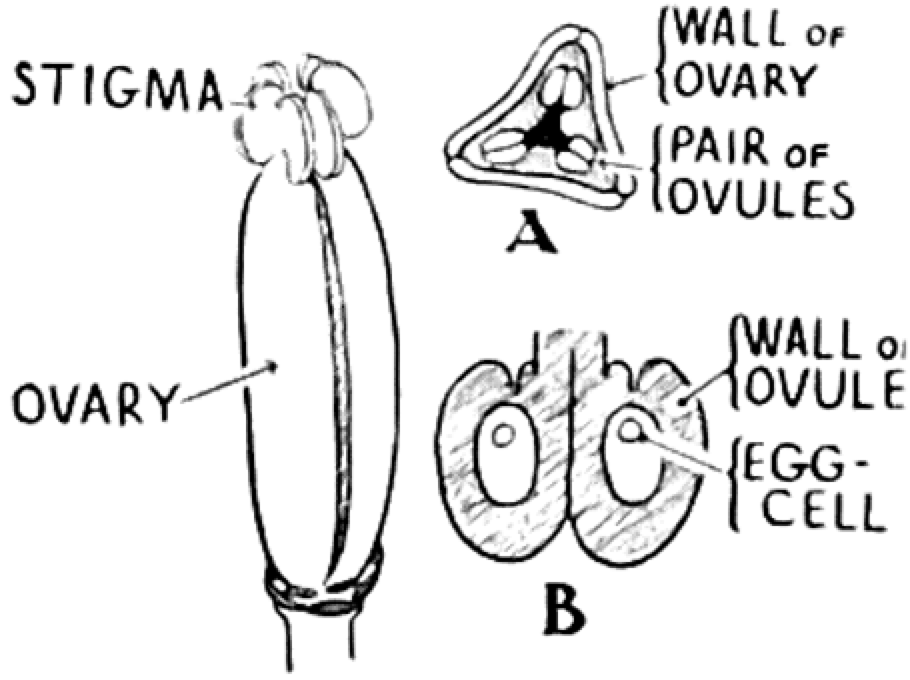
The 'pollen dust' that you shake from hazel catkins in early spring is made up of the male reproductory cells of the hazel: indeed each particle of the 'dust' carries a living male cell and if you examine one of these pollen 'grains' under a microscope you will see that it is rather like a tiny balloon. Each grain contains a sticky liquid that is rich in protein and it is because of the protein in it that honey-bees gather pollen so eagerly: pollen is the honey-bee's 'meat' or body-building food, whereas honey—which is composed mainly of sugar—is simply an energy food. Of course you do not often see bees gathering hazel pollen because the hazel catkins frequently shed their golden dust while the bees are still inside their hives; but any pollen that they gather from other flowers later in the year is similarly rich in protein because the male reproductory cells of any flowering plant are made up



This hazel pollen is not just a cloud of dust. The microscope shows us that each speck has the shape of a girdled ball.

largely of protein. Yet, however tiny each pollen grain may be, it carries inside it the miraculous power to reproduce all the distinguishing characteristics of the species from which it came. Each speck of the black pollen dust from the wild red poppy contains within it in some mysterious way the very shape and size and flaming colour of the poppy that made it; each pollen grain from whatever flower—red from some of the lilies, orange from the dandelions, or purple from the rose-bay willowherb—carries within its tiny covering the power to reproduce all those features of the parent plant that enable us to say what kind of plant it is—lily, dandelion, willowherb, and so on.

But, normally, no new life can begin, no embryo can be produced, until a male reproductory cell from one grain of pollen dust unites with a female reproductory cell of the same or of a very similar species. Pollen, as you know, is produced by flower **stamens,** but where are the female cells to be found? Many flowers contain at or near their centre a fleshy case or box to which we give the name **ovary.** The larger the flower, the larger the ovary as a rule so it will be as well for you to examine a large flower to begin with. A tulip, a lily, a poppy, or a gladiolus flower will do quite well. If the young ovary of any of these flowers is cut with a sharp knife, you will see that it contains large numbers of small green 'bodies' just about visible to the naked eye. Each one of these is called an **ovule,** and hidden away inside each ovule is a female cell, fully protected by the green covering of the ovule. This female cell—or egg-cell as it is sometimes called—contains within it the power to reproduce all the distinguishing characteristics of the plant on which it grows; it is, you see, very similar to a pollen grain in this respect; but whereas the pollen grains can be carried away from the stamens to other flowers, the female cells are always retained inside the ovary. Can you guess the important reason for this?



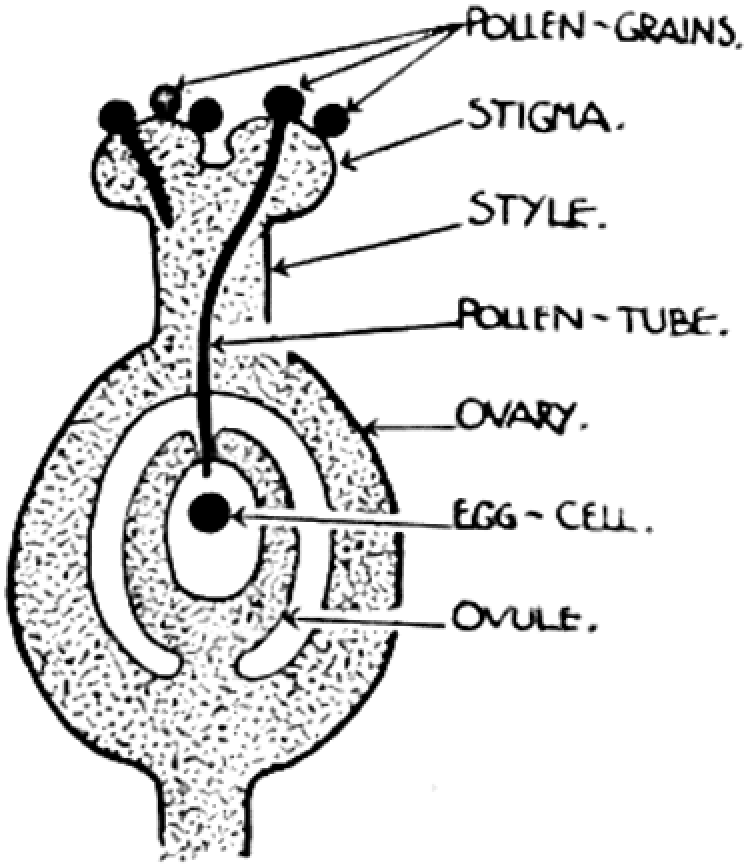
If you make a horizontal cut across this tulip ovary, you will be able to see pairs of ovules with the naked eye (A); but you will need a microscope to see the egg-cells in these ovules (B).

When a new life begins—when the seed is forming—it needs to be supplied with food so that it can grow. If the union of male and female cells took place outside the ovary, the developing embryo might die for lack of suitable protection and nourishment, so that—in the case of plants and indeed of many animals also—the female reproductory cell remains safe and sound inside the female parent. In this way the tiny embryo can be fully nourished and protected.

You should notice, however, that although the embryo grows and develops inside the ovary its power of growth and its characteristics are provided not only by the female cell that was already in the ovary but also by the male cell brought by the pollen grain. The ovary of the flower plays such a large part in the production of seed that we are liable to forget that the new young plant that grows when the seed germinates owes its very life and general appearance as much to the male cell which came with the pollen grain as it does to the female cell. The nourishment provided in the ovary enables the embryo to grow and take shape; but the details of appearance and other characteristics of the offspring plant (colour and perfume of flowers, hardiness, and so on) were already present, in some strange and hidden way, in the two reproductory cells *even before those two cells joined together to start the new plant on its way*—before **fertilization,** as we call it, took place. The power of life that is contained in these minute reproductory cells is indeed quite astonishing. Man has learnt a great deal about the reproductory cells of both plants and animals, but he is quite unable to explain the life that is within them.

You will now be able to understand why one species of living thing cannot breed with a totally unrelated species. A pollen grain from a poppy, for instance, could not possibly fertilize the female cell of a lily, because the characteristics carried by those two cells are so very different—the offspring of such a union could not possibly be sufficiently like either parent. When two different species are very closely related cross-breeding between them can, however, take place. A horse and a donkey are, for example, sufficiently alike for them to be quite capable of breeding together. The offspring in this case is the mule, but the mule is really a freak of nature because it cannot go on breeding other mules itself. In the same way, tigers and lions have been bred together to produce a **hybrid** offspring; but such 'crosses'—even between the most closely related species either of animals or of plants—are usually the result of man's interference: they rarely occur naturally. Remember the reason—it is because the reproductory cells of different species carry characteristics that cannot readily mingle.

How exactly does fertilization in plants take place? How do the living male contents of the tiny pollen grain reach the contents of the female cell in the ovule so that union can take place between themand a new life begin? Any ovary that you examine will give you a clue to the solving of this problem. Careful examination will usually reveal a sticky surface either on top of the ovary itself, as in the case of the tulip, or at the end of a projection attached to the ovary, as in the case of most lilies. Such a projection is called a **style** and the sticky surface is called a **stigma.** Any pollen that is carried on to the stigma—maybe by the wind, maybe by some insect—gets stuck on the syrupy surface. If it is pollen from an unrelated plant—and it often is—nothing important happens; *but if it is pollen from a suitably related flower* the tiny grain begins immediately to grow a 'root' into the ovary. This 'root' is called a pollen tube and it grows until it reaches an unfertilized ovule. Upon doing so it penetrates the ovule, bursts open, and its male contents unite with the contents of the female cell. The minute embryo begins immediately to grow from these united

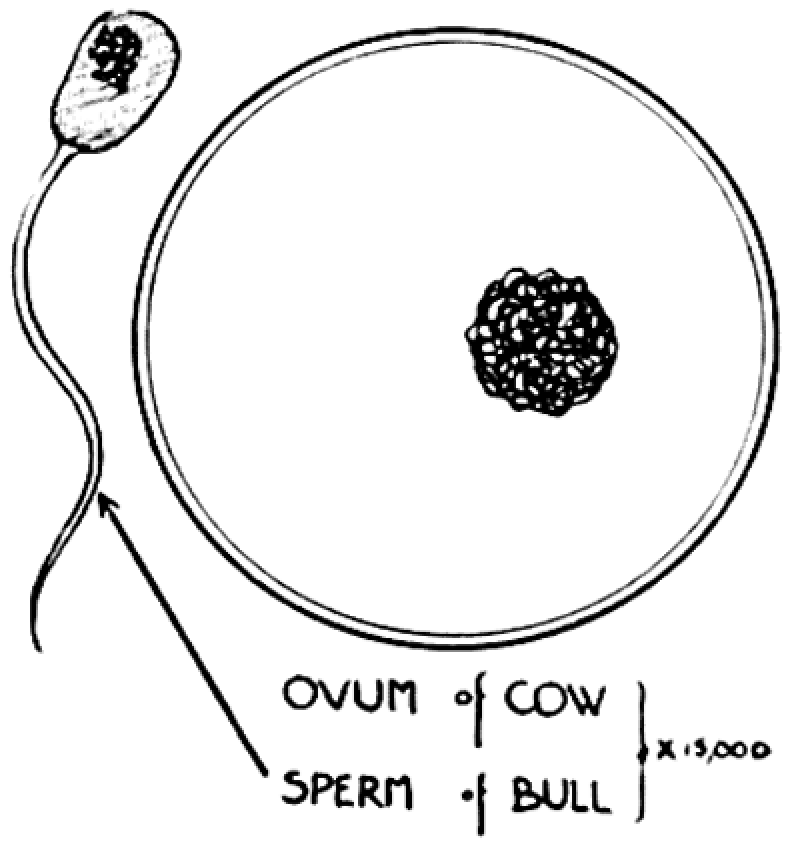


Two of the pollen grains on the stigma of this ovary are thrusting their pollen tubes towards the ovule. When one of them reaches the egg-cell, fertilization will take place, and the ovule will grow into a seed.

cells and the development of a ripe seed is a matter only of time and nourishment.

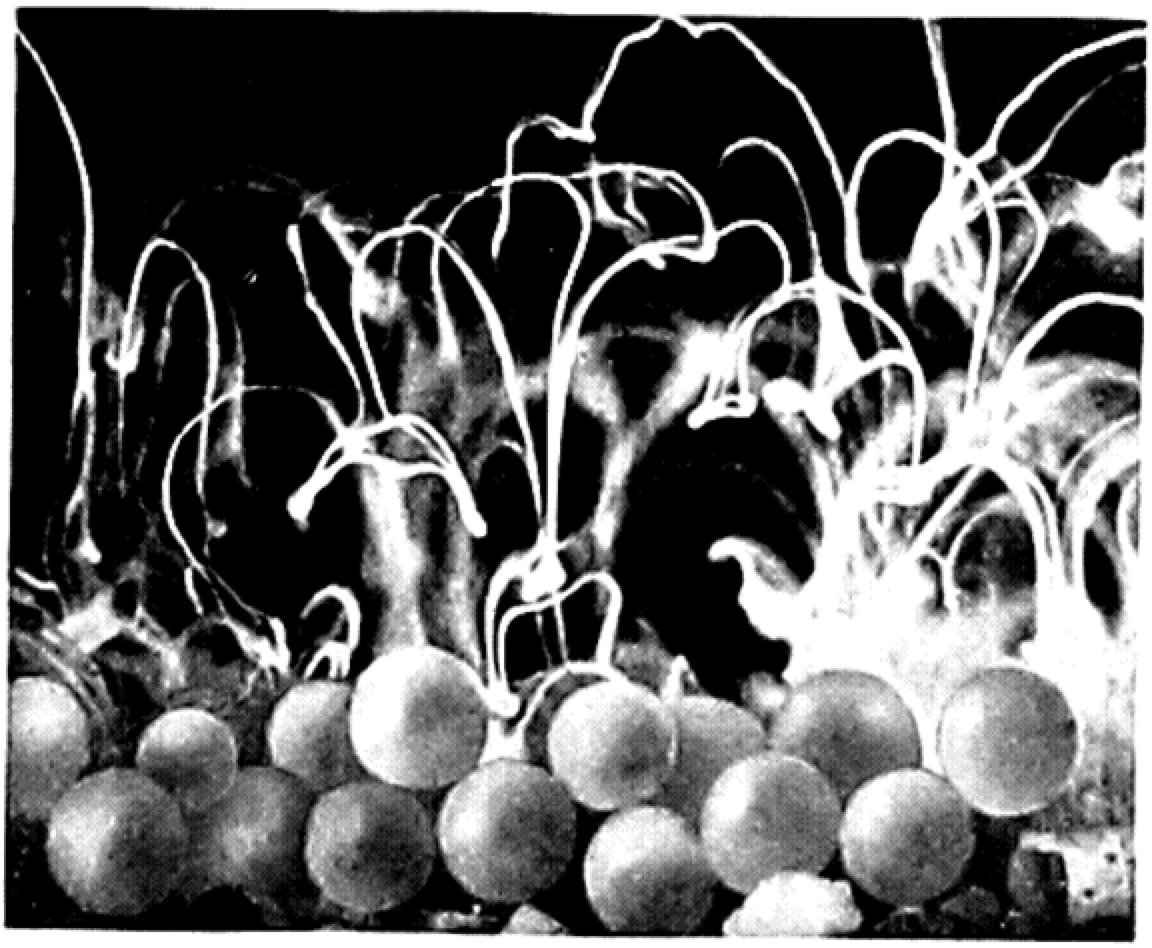
## THE REPRODUCTORY CELLS OF ANIMALS

Animal embryos begin their lives in very much the same way as plant embryos: a male cell called a **sperm** unites with a female cell called an **ovum** or **egg-cell** and a new life comes into being. As in the case of plants, these reproductory cells of animals carry within them the means of reproducing the exact characteristics of the kind of animal from which they come. Thus when the sperm of a male salmon unites with the ovum of a female salmon, the offspring bears all the exact features of the salmon species, even down to such details as the number of scales!



Here you see the male reproductory cell or sperm of a bull, and the egg-cell of a cow. Notice that they are very highly magnified. Why does the sperm have a tail?

In all important respects the reproductory cells of animals are similar to the pollen grains and egg-cells of flowering plants. The main difference is that each sperm has a hair-like tail that enables it to swim. When mating takes place between the male and female of any species the male animal releases enormous numbers of sperm (think by way of comparison of the enormous numbers of male cells in a cloud of hazel pollen); and the tail on each sperm enables the male cell to make the last stage of its journey to the female cell. The tiny tail corresponds really to the pollen tube that grows into the ovary of a flower. Out of the thousands of millions of sperm that are released at a single mating, only *one* is necessary for the fertilization of one ovum; and the first one to reach the ovum or egg-cell causes the development of the new animal embryo to begin. Remember that in these first early stages of its life the embryo is usually *microscopically* small; and remember also that it will grow into a calf, or a foal, or a human child according to the species of animal concerned. In the case of most freshwater fish—and indeed of most sea fish too—this release of sperm can be watched quite easily because the female fish deposits her egg-cells (complete with an enclosing supply of food) on the bottom of the sea or lake or



This cloud of trout milt is made up of millions of trout sperms. Notice the egg-cells or *ova* on to which the milt is falling.

stream in which she lives. The male fish comes along and as he swims over the deposited eggs he discharges clouds of sperm upon them. This 'milt,' as we call it, falls among the egg-cells and fertilization takes place. Much the same sort of thing happens also in the case of frogs and toads. When you gather frog spawn or toad spawn you are gathering clusters of unusually large egg-cells each one of which is surrounded by a supply of jelly-like food.

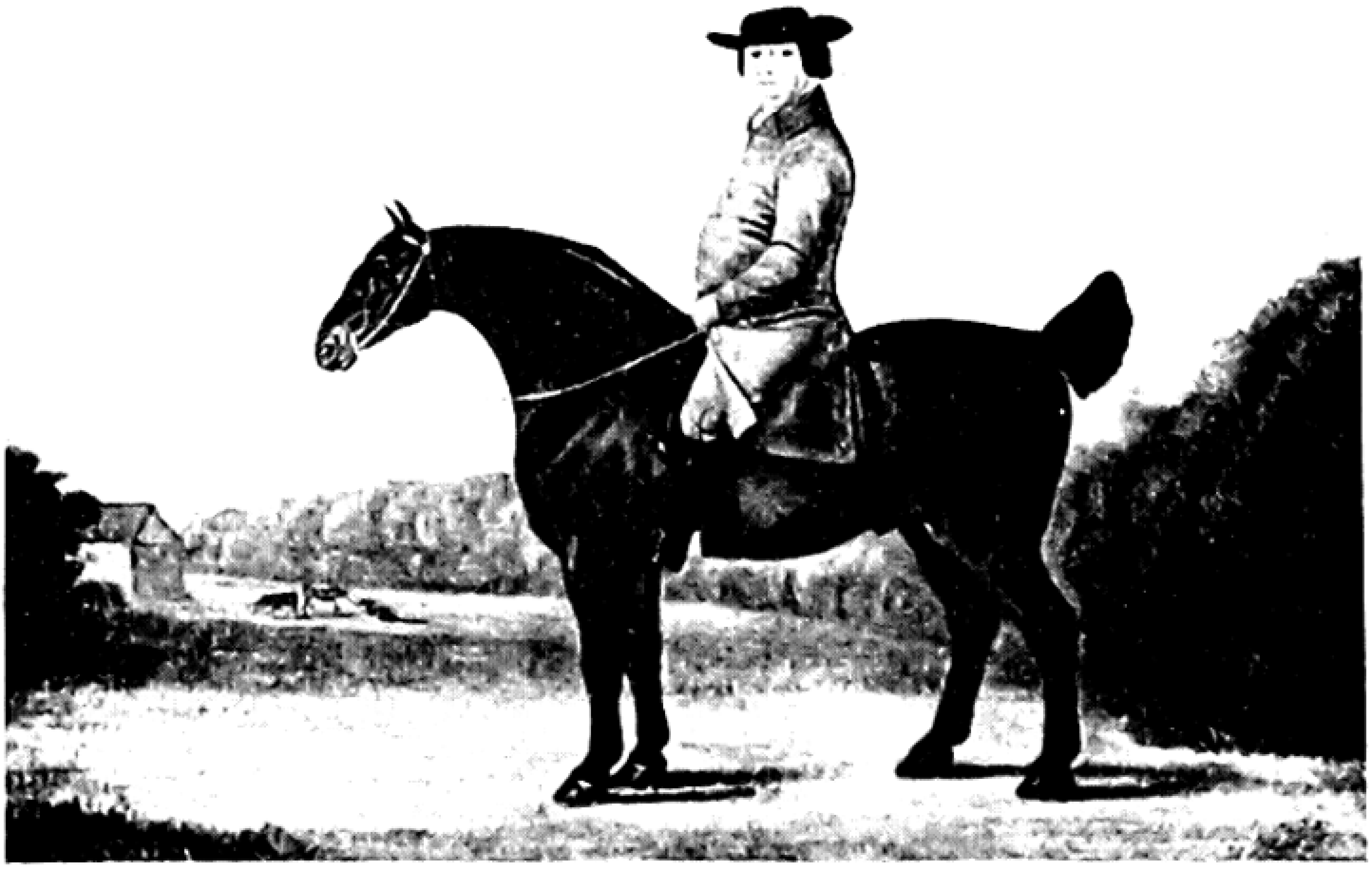
Frog spawn consists of a mass of egg-cells (A) laid by the female frog. After fertilization by 'milt' from a male frog the embryos begin to develop (B).

The animals with which we are most familiar—the birds and mammals (our pets, for example, and the domesticated animals of the farm)—are either male or female, but not both; and in each case the male animal produces the minute sperm-cells and the female produces the tiny egg-cells. There are, however, a number of 'lower' animal species whose individuals produce both sperm and ova: each individual is both male and female. This is true of the earthworm and also of the snail. Nevertheless this does not mean that a worm or a snail can produce its young without being fertilized by sperm from another worm or snail. The creatures are not *self-fertile*--the female egg-cells of each individual can be fertilized only by sperm from a different individual of the same species. The fact that such animals are *bisexual* means that each one of them can be either mother or father—but not without the help of another earthworm or snail whichever the case may be.

### HOW DO BREEDERS IMPROVE FARM ANIMALS?

Before being able to understand this lesson, you will need to realize that two individuals *even of the same species* can be very different in many ways: cattle, for example, all belong to one species but, as you know, there are many different breeds of cattle—Shorthorns, Ayrshires, Guernseys, Herefords, and the rest. These different breeds can be mated together quite easily if need be. Even the animals in one breed can show important differences—some are bigger than others, some are better milkers, some are more lively, and so on. Indeed as you learnt in Book III most of our present-day cattle, pigs, sheep, and poultry are better producers of milk, meat, wool, eggs, etc., than their ancestors of two or three hundred years ago. How were breeders like Robert Bakewell (1725–95) and the Colling brothers (Robert, 1749–1820, Charles 1751–1836) able to improve our farm live-stock by breeding? As you have just been told *all* the characteristics of living things have been handed on to them from their ancestors by means of the male and female reproductory cells. Yet our modern live-stock possess good characteristics that the herds and flocks of medieval cattle and sheep did not have. How can this be?

You must remember always that good housing, good management, and good feeding of live-stock will give the *inborn* characteristics a chance to develop; but those characteristics—deep milking, rapid fattening, thriftiness, and so on *are* inborn: no amount of feeding will make a naturally poor milking cow into a good milker. Her capacity to be a good milker comes to her either from the bull or the cow—or both—that were her parents. No farmer that persists in using poor bulls on his dairy cows can expect the calves to grow into good dairy beasts. The poor characteristics of the bulls will be handed on to the calves by the bulls' sperm. What then does the breeder do in order to improve his herds and flocks? Where do the special characteristics, like the deep milking and the rapid fattening of cattle, for instance, come from in the first place? And how does the breeder gather these characteristics together into the animals of one herd or one breed?



This quaint picture of Robert Bakewell was painted during his lifetime. About how long ago was that?

## THE INHERITANCE OF SINGLE CHARACTERISTICS

Let us think of one feature at a time—the possession of horns by certain breeds of cattle, for example. Some breeds of cattle are quite hornless—we call them *polled cattle*—and Red Poll dairy cattle or Aberdeen Angus beef cattle are good examples. Most breeds of cattle, however, have well-developed horns. The polled and the horned conditions of cattle are characteristics that are handed on through the breeding cells. If a polled bull and a polled cow are mated the sperm from the bull and also the egg-cell from the cow will carry the polled characteristic and, as you would expect, the embryo develops into a calf that is quite hornless. In the same way the mating of horned cattle leads to the birth of calves that grow horns. But what will happen if a polled cow is mated to a horned bull? The egg-cell of the cow carries the hornless feature while the sperm of the bull carries the horned feature. The offspring cannot possibly be *exactly* like both parents. We can make one of three guesses about the calf that is born from the union. It will be:

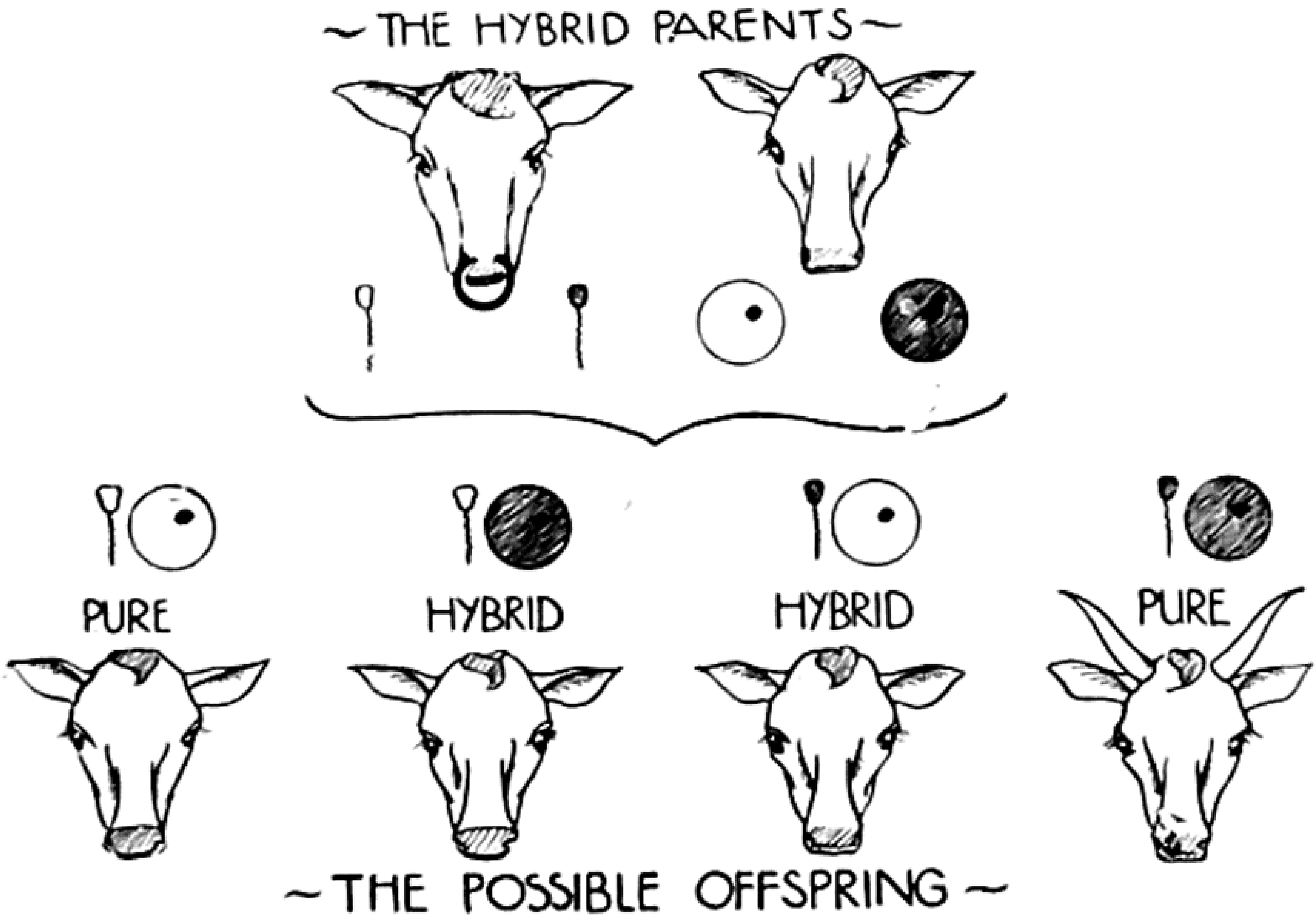
(*a*) Hornless,
(*b*) Horned, or
(*c*) It will have horns of some intermediate length.

Nothing else is possible.

Experience of a large number of such matings has shown that the resulting calves are always hornless. This seems like a quick way of getting rid of horns in cattle—and as you know that is what many farmers would like to do because of the damage caused among cattle by their horns. Unfortunately, however, the *breeding out* of undesirable characteristics is not so easy as that. Remember that although the hybrid calves from this cross-breeding do not themselves possess horns, the horned *factor* has nevertheless been given to them by the sperm from the horned bull parent; and it is quite possible that this horned characteristic will be present in some of the reproductory cells that these hybrid calves will produce when they grow up and begin to breed. Indeed that is exactly what does happen. We say that the hybrid calf carries both the horned characteristic and also the polled characteristic but that the polled condition is *dominant*—that is to say it does not allow the horned condition to show in the hybrid calf. *But*—and you must give special attention to this—no matter whether the hybrid beast is a bull or a heifer, exactly one-half of the reproductory cells that it produces will carry the factor for hornlessness and exactly half will carry the horned characteristic. *These sperms and egg-cells are, you see, quite pure—not hybrid like the animal that produces them.*

Let us work out what kind of calves can be born if we mate a hybrid cow and a hybrid bull of this kind. For every one of the bull's sperms containing the horned factor there will be another that carries the hornless factor. You will see that these two 'kinds' of sperm are represented in the diagram. In the same way, for every one of the cow's ova containing the horned factor there will be one that carries the hornless factor. If you wish, you can think of the two sperms as two halfpennies and of the two ova as two pennies. Let one halfpenny and one penny be tails up to represent the 'hornless' reproductory cells, and let the other halfpenny and the other penny be heads up to represent the 'horned' cells. Put the coins on the desk in front of you.

Now when fertilization takes place one sperm will unite with one egg-cell. By juggling about with your coins you will see that various different unions can be brought about to produce a calf:



Examine carefully the sperms of the bull parent and the ova of the cow parent. The shaded ones carry the horned factor and the unshaded ones are 'hornless.' As you see, the kind of offspring depends entirely on the sorts of sperm and ova that unite when the parents mate.

(1) A 'tail' halfpenny and a 'head' penny ('hornless' sperm and 'horned' egg-cell).

(2) A 'tail' halfpenny and a 'tail' penny ('hornless' sperm and 'hornless' egg-cell).

(3) A 'head' halfpenny and a 'head' penny ('horned' sperm and 'horned' egg-cell).

(4) A 'head' halfpenny and a 'tail' penny ('horned' sperm and 'hornless' egg-cell).

Any calf born from the mating of the hybrid bull and the hybrid cow will be formed from *one* of these four unions. Before you read on try to forecast whether or not the animals born from these four possible fertilizations will grow horns or remain hornless. The possible results are:

(1) A hornless calf that is hybrid like its parents.

(2) A hornless calf that is pure like one grandparent.

(3) A horned calf that is pure like another grandparent.

(4) A hornless calf that is hybrid like its parents.

Thus the chances are three to one that the calf will be hornless; and of the three possible hornless calves only one will be pure for the hornless factor. The other two will carry the horned factor in a hidden way, i.e. they will be hybrids as far as this factor is concerned. You should examine the diagram carefully in order to make sure that you understand these possible results.

## A PRACTICAL BREEDING PROBLEM

Now here is a breeding problem for you to solve. Start off as we did before with two parents that are pure for one characteristic—but this time let the characteristic be colour. Choose a red Shorthorn bull and a white Shorthorn cow. The difference between this characteristic (colour) in Shorthorns and the one we chose before—the horned or hornless condition—is this: whereas the horned condition does not show in the hybrid because the hornless condition is dominant, *both red and white will show in the hybrid Shorthorn calves because neither colour is dominant over the other in this breed.* The hybrid calves will be mixed in colour as you learnt on page 120—they will be roan. In order to discover what colour of calf will be produced by two roan hybrid parents, you will need to think out what colour is 'carried' in the sperm and the ova of these two hybrid parents. Then get to work with your coins, and by bringing the halfpennies (sperm) and the pennies (ova) together in imaginary fertilizations, you will be able to say exactly what colour the offspring could be. Remember that each reproductory cell can 'carry' one colour only—not both. Your teacher will check the answer for you.

## GATHERING SEVERAL CHARACTERISTICS TOGETHER INTO A NEW BREED

The simple crossing of two breeds as in the examples you have been studying cannot possibly give rise to a new breed in the first generation. The offspring from such a first cross have no breeding purity about them at all—whatever their appearance may be, they are *all* hybrids. We know that this is so because when these offspring of a first cross are mated together—when, as we put it, they are *inbred*—they always produce a very mixed bag of descendants indeed. The breeder may very well find himself presented with some more hybrid offspring, together with some that are pure like their grandparents. Even in this *second* generation there seems to be no progress at all so far as the production of a *new* pure breeding strain of animal is concerned; indeed it would appear that the breeder is landed back with the types he had at the beginning. But is this necessarily true? Are there, perhaps, some new pure strains in this second generation? Let us think about the offspring that came from the crossing of the red bull and the white cow.

Some of the 'grandchildren' are pure for redness and some for whiteness like their grandparents. But along with the pure redness or the pure whiteness that came from one grandparent there may very well be some other pure characteristic that came from the other grandparent. For example, a calf from the hybrid cattle may be pure for the redness that came from its grandfather and pure also for, say, thriftiness that came from its grandmother. In such cases the breeder has really got something new; and if he mates together new pure types of this kind he can start a new strain—even a new breed—of cattle, or of any other species of animal. Remember, however, that he cannot do it by a first cross. He has to cross-breed first, and then he has to inbreed selected offspring from succeeding generations.

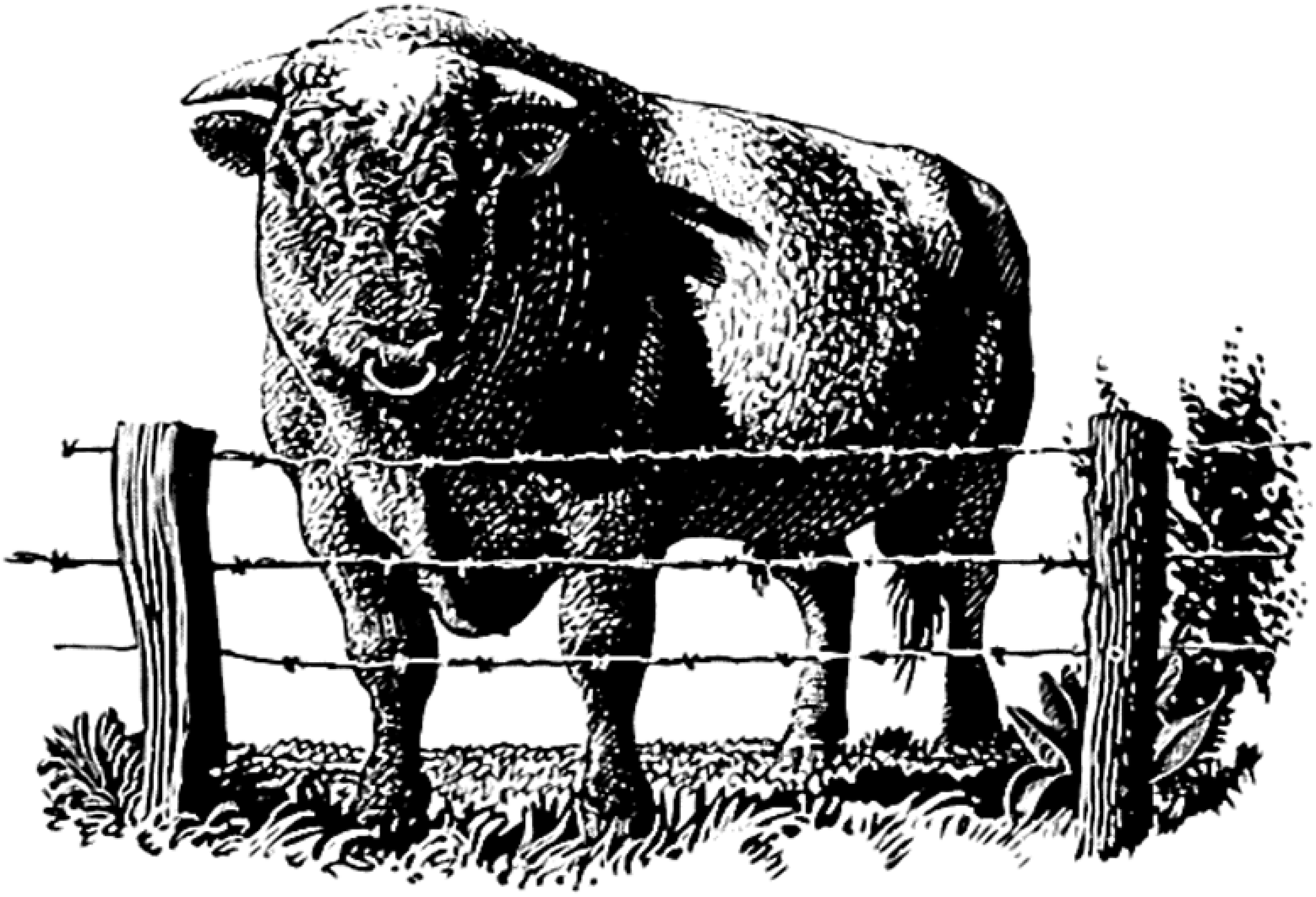
This process is called 'fixing' a new type; and you should notice that in 'fixing' a type, he can use for inbreeding only that small percentage of offspring that carry a combination of the characteristics that he is trying to gather together into each of the animals of his herd. Notice also that in 'fixing' a new type the breeder does not *create* any new characteristics at all. Only nature can do that. What the breeder tries to do is to gather together into one strain several characteristics that *already existed* in a number of different animals. Thus a breeder may produce a whole herd of very deep-milking dairy cattle, but before he can do it he has to find at least one cow that is a deep milker. The ability to give a large volume of milk was given to his chosen cow, or to her ancestors, by a trick of nature, not by a trick of the breeder. The deep-milking ability can, however, be handed on by her reproductory cells to her offspring—both bulls and heifers—and the breeder makes use of this fact. The 'tools of his trade' are (*a*) *Careful selection of breeding stock*, and (*b*) *Cross-breeding followed by inbreeding*.

## BAKEWELL'S FAMOUS BREED OF SHEEP

Stock breeders down the ages have cross-bred and inbred their cattle, sheep, and so on in order to bring together the special characteristics that they were seeking to 'fix' in their herds and flocks. The early breeders like Robert Bakewell (1725–95) and his host of imitators selected for mating only those parent animals that had the characteristics that they were trying to 'fix' in their animals. Bakewell's first breeding experiments were done with sheep. He was a very experienced farmer, and he knew quite well that the sheep of one breed, and even those in one flock, differed very considerably one from another; some of them—like some men, for example!—fattened much more easily than others. They were more thrifty as we say; and from the farmer's point of view such animals are much more profitable than the thinner sheep—the poor 'doers'—who eat just as much food but provide less mutton! In the same way there is often a great deal of difference between the quality of meat produced by different sheep. Bakewell set to work to raise a breed in which the important qualities—thriftiness, quality of meat, and so on—were combined. In order to raise his famous breed of *New Leicester sheep*, Bakewell took care to mate together only those rams and ewes (male and female sheep) that possessed the characteristics that he wanted. In this way his flocks were gradually 'purified'; the desirable characteristics were gathered together and the undesirable characteristics were bred out.

## WHAT IS A PROVEN SIRE?

You should take special notice of the importance of the male animals on a farm—the bull, the boar, the cock, the several rams, and the visiting stallion. As a rule only one or two male animals are used for mating with a large number of females. Let us think about this in connection with cattle. In time the bull—or perhaps the two bulls—affects all the cattle on the farm, and the desirable characteristics that he carries in his sperm—production of copious milk, rapid production of prime beef, resistance to disease, thriftiness, and so forth—are given to all his descendants, to all the cows in the herd. No wonder the quality of the bull is important in the breeding of cattle. Of course you can never judge a bull by looking at it only; nor can you test it for such characteristics as milk production—the bull has to prove his qualities by producing desirable offspring, and when he has done this he is said to be a 'proven sire.' It takes five or six years for a bull to prove itself in this way; and that is why farmers nowadays tend to keep their bulls longer than they used to. An old bull that is 'proven' is often much more valuable than a young bull, no matter how lively the latter may be. The old pioneer breeders laid the foundation of the splendid animals we have to-day by continuing to use good sires when they had found them, or when they had bred them.



All the daughters of this sturdy Shorthorn bull are good milkers because all his sperm carry the deep-milking qualities of his mother. He is a valuable proven sire.

Improvements are of course still being made, but the general methods of selective breeding are the same. Science has helped to some extent because it has enabled us to measure the desirable qualities of farm stock—rate of live-weight gain, milk yield, and so on. Nevertheless breeding is to-day what it always was—

more of an art than a science; and there is still a good deal of luck in it too.

You may wonder why nature does not follow a 'close inbreeding' plan like this, but you must remember that, although the resultant breeds of farm stock may have many desirable characteristics so far as the farmer is concerned, farm animals are not as a rule so hardy as the offspring of mixed breeding. If you have had much to do with animals you will know how true this is. It often happens that pure-bred dogs, for instance, or pure-bred cattle, are much less hardy than mongrel dogs or cross-bred cows—the purer breeds require much more careful management if they are to thrive. Wild cattle or wild dogs, or indeed the wild ancestors of any of our domesticated animals, could very well look after themselves without the help of man, just as our wild birds and mammals fend for themselves to-day; but our farm animals would have a poor time of it if we turned them adrift to feed and shelter themselves. The remote ancestors of Bakewell's New Leicester breed would certainly have been able to survive on the poor grazings of hill and mountain pastures; but Bakewell's sheep were suitable only for the rich grazings of lowland arable farms. Gain in the quality of farm stock is usually accompanied by a loss of hardiness, so that the farmer is compelled to provide better food and better management for his finer stock. Nature, however, does not provide these special conditions. Wild creatures do not survive if they are not hardy, and wild animals of any particular species—foxes, squirrels, birds, reptiles, fish, and so on—choose their mates quite freely. Chance meetings and their own desires are the only 'rules' of their matings; special selection of mates has nothing to do with it at all. In this way the various characteristics, including the characteristic of hardiness, are scattered throughout the populations of each wild species quite widely. If man suddenly vanished from the earth many of his domestic animals would vanish with him, but the wild species of animals would continue to flourish—nature's haphazard breeding would ensure this very thing.

This is the only photograph in existence of a wild wood-mouse. Wild creatures are born as a result of 'natural mating' and they can fend for themselves; but farm animals—which are born as a result of regulated mating—need constant care and protection. Can you explain the difference?

The same thing is true in the world of plants; and this is not surprising, because the *fundamental* method of breeding—the union of a male cell with a female cell—is the same for both animals and plants as you now know. Most farm and garden crops have been produced by the careful breeding of selected strains.

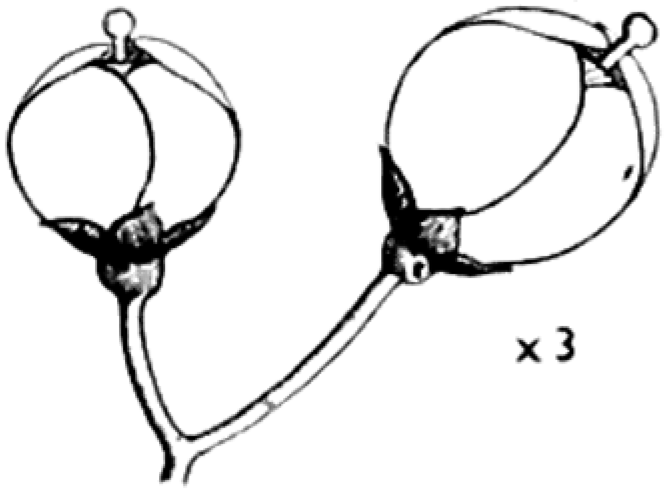
The garden cabbage is a better vegetable than the native wild cabbage, but the garden variety is much less hardy than its wild ancestors. As you know, our inbred garden cabbages will grow to perfection only in a rich, moist soil; but the wild cabbage ekes out a sparse living even on the poor soils of the sea coast. The same thing can be said of all our important farm and garden crops—like the cultivated cabbage, they yield more food than their wild *progenitors*, but they survive only under carefully chosen conditions.

How do wild plants retain the hardiness that enables them to grow quite well without the help of gardener or farmer? As in the case of wild animals, we find that the 'natural' breeding methods are responsible. In the world of wild flowering plants a great deal of *cross-pollination* takes place—there is no selective breeding at all. And this scattering of the pollen—perhaps by the wind, perhaps by insects, or maybe even by water—ensures that the characteristics that make for hardiness are distributed throughout the whole population of any particular species of flowering plant. There is, of course, a great deal of self-pollination also; but cross-pollination is always a possibility unless the plant breeder 'steps in' to control it.

## THE PRODUCTION OF CROP SEED

You are now in a position to understand the great care that has to be taken by seed-growers when they are producing seeds from crop plants that cross-pollinate easily. The various 'greens,' for example—kale, Brussels sprouts, cabbage, broccoli, and so on—are readily cross-pollinated because they all belong to one species. In order to produce pure seed from any one of them the grower has to ensure that no other flowering crop of 'greens' is planted within easy flying distance for roaming insect visitors. When you buy a certain variety of cabbage you quite rightly expect to get that variety in return for your money. Remember, however, the trouble to which the seed-grower had to go in order to avoid cross-pollination. It is no wonder good seeds of these things are expensive. *Controlled* breeding, you see, whether of plants or animals, is difficult because it is an attempt to prevent the operation of natural breeding. The breeder, whether of plants or of animals, usually has to take steps to avoid the free mixing of strains (*not species!*) that nature prefers.

In the world of wild plants, however, man does not attempt to interfere; and cross-pollination—nature's method of scattering characteristics throughout each species—is quite common. In order to ensure a measure of cross-pollination certain flowers frequently make use of an interesting device: they 'ripen' their stigmas and stamens at different times so that the pollen has to be carried from one plant to another in order for fertilization to take place. You should examine as many wild flowers as possible to see which of them arrange for cross-pollination by maturing their anthers and stigmas at different times and which of them use some other device for achieving this purpose. Make a list of your discoveries.

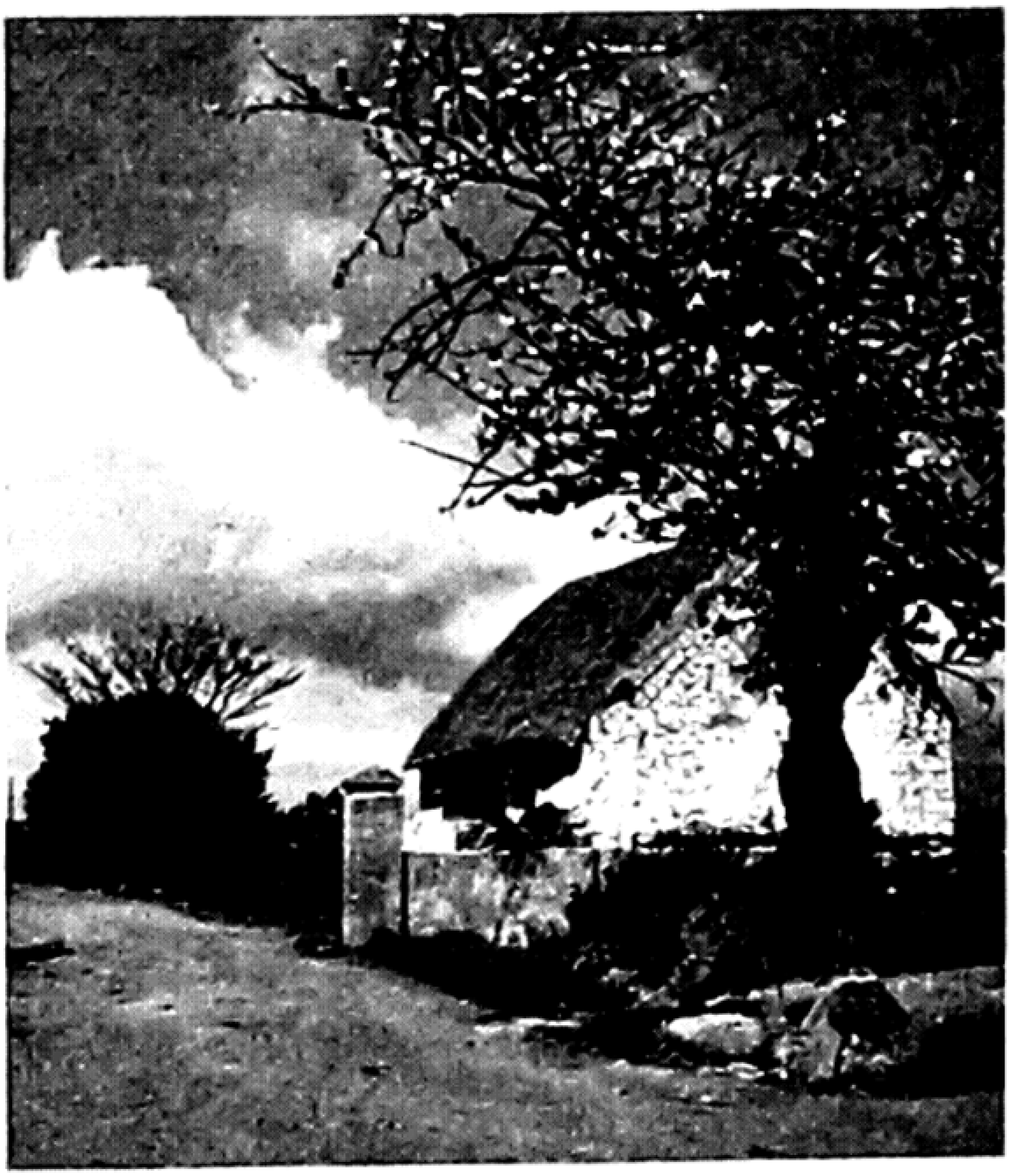


The stigmas of these opening 'May' blossoms (hawthorn) are exposed before the stamens ripen. Why is this?

## NATURE IS IN CONTROL

It is very necessary for you to realize that nature has the ruling hand in all this selective breeding that men undertake. If our breeders could produce just what animals or plants the human mind is capable of imagining, we might find ourselves provided with some very strange creations indeed! Fortunately, however, nature puts a stop to too much very close inbreeding. It is very true that you cannot travel very far from 'the nature of things' without a severe check. A very good example of the check that nature places on too much inbreeding is provided, for example, by numerous fruit-trees. Many strains of closely inbred fruit-trees—cherries especially—are *self-sterile*. Their flowers are sterile not only to their own pollen *but also to pollen coming even from another tree of the same variety*. The male and the female reproductory cells are there in the flowers all right, but they do not unite in order to produce an embryo. Such cherries have been so closely inbred that nature has stepped in to prevent any more inbreeding. When she does that man has to stop; there is nothing else he can do about it. The same thing happens at the other extreme of breeding. If man attempts to cross-breed animals that are not sufficiently closely related for normal breeding to take place, he may be successful up to a point—as in the case of the horse and donkey cross which, as you know, produces the mule; but no further breeding is possible because the mule is sterile. It is clear that both close inbreeding and wide cross-breeding are opposed to nature's purposes—she has no liking for extremes.

It is of course very important for the fruit farmer to know which of his fruit-trees are self-sterile and which are self-fertile. If he planted a whole orchard with a variety of cherry-trees that were self-sterile he would never gather any cherries at all! He is compelled to plant some trees of at least one other carefully chosen variety of cherry so that fertilization can take place. The same thing is true to some extent both of apple-trees and of pear-trees—orchards of these fruits are made up of a mixture of varieties so that the best possible yields of fruit can be ensured as a result of cross-pollination. You should note that—because of this



Unlike many garden cherry-trees, this wild cherry is self-fertile.

cross-pollination among the cherries or among various strains of apple or different varieties of pear—the seeds of most cherries, apples, or pears are of mixed parentage. This is one of the reasons why you can never be sure what variety of cherry-, apple-, or pear-tree will result if you sow the seeds of these various fruits. You do not know the full parentage of the stones in your cherries or of the pips in your apples and pears. If you wish to propagate your fruit-trees and keep them true to variety you will need to use vegetative methods.

## THINGS TO DO

(1) Write a composition entitled 'Good Feeding and Good Management Alone can never produce Good Livestock.'

(2) Use single sentences to answer the following questions:
   (*a*) What do we call a group of living things that are sufficiently alike to breed easily and regularly?
   (*b*) Why is a potato 'set' not a true seed?
   (*c*) Plants very often reproduce themselves by severing a portion of a shoot or root. What name do we give to this kind of reproduction?
   (*d*) What is the approximate size of most infant plants and animals when they first begin their lives?
   (*e*) Why do living things often show some resemblance to both the parents that produce them?
   (*f*) What is pollen?
   (*g*) What names do we give to the reproductory cells of male and of female animals?
   (*h*) What is a mule?
   (*i*) When *exactly* does fertilization take place in plants and animals?

(*j*) Why are wild species of plants and animals never self-sterile?

(*k*) What is a proven sire?

(*l*) In what way are closely bred plants and animals *inferior* to their wild ancestors?

(3) Find out from your closest farmer friend what system of breeding he uses on his cattle or pigs. Write a paragraph explaining what he tells you. Don't forget to find out as much as you can about the bulls or boars he uses.

(4) Collect and draw in your Country Book at least six different ovaries from either wild or garden flowers. Name them carefully and indicate their stigmas (and styles if they have them) with neat arrows. Try also to make a drawing of one that has been opened to show the ovules inside.

(5) Examine twelve different flowers and in your Country Book make a list of the colours of their pollen.

(6) An old country saying says: 'The bull is half the herd.' Write a composition explaining the meaning of this.

(7) Collect some apple pips from a known variety of apple and sow them in pots of soil. Write a short composition saying whether or not the seeds are likely to develop into trees of the same variety as the parent tree.

(8) The title of this chapter is followed by a question mark. Write a short clear essay explaining why it is a question mark and not a full stop.

(9) Write a short paragraph entitled 'It is better to grow potatoes from 'sets' rather than from true seeds.' (Try to think out all the advantages.)

[*Note to the teacher:* Twigs of beech, oak, and sycamore, taken from the canopies of mature trees, will be helpful in one of the lessons of the next chapter.]

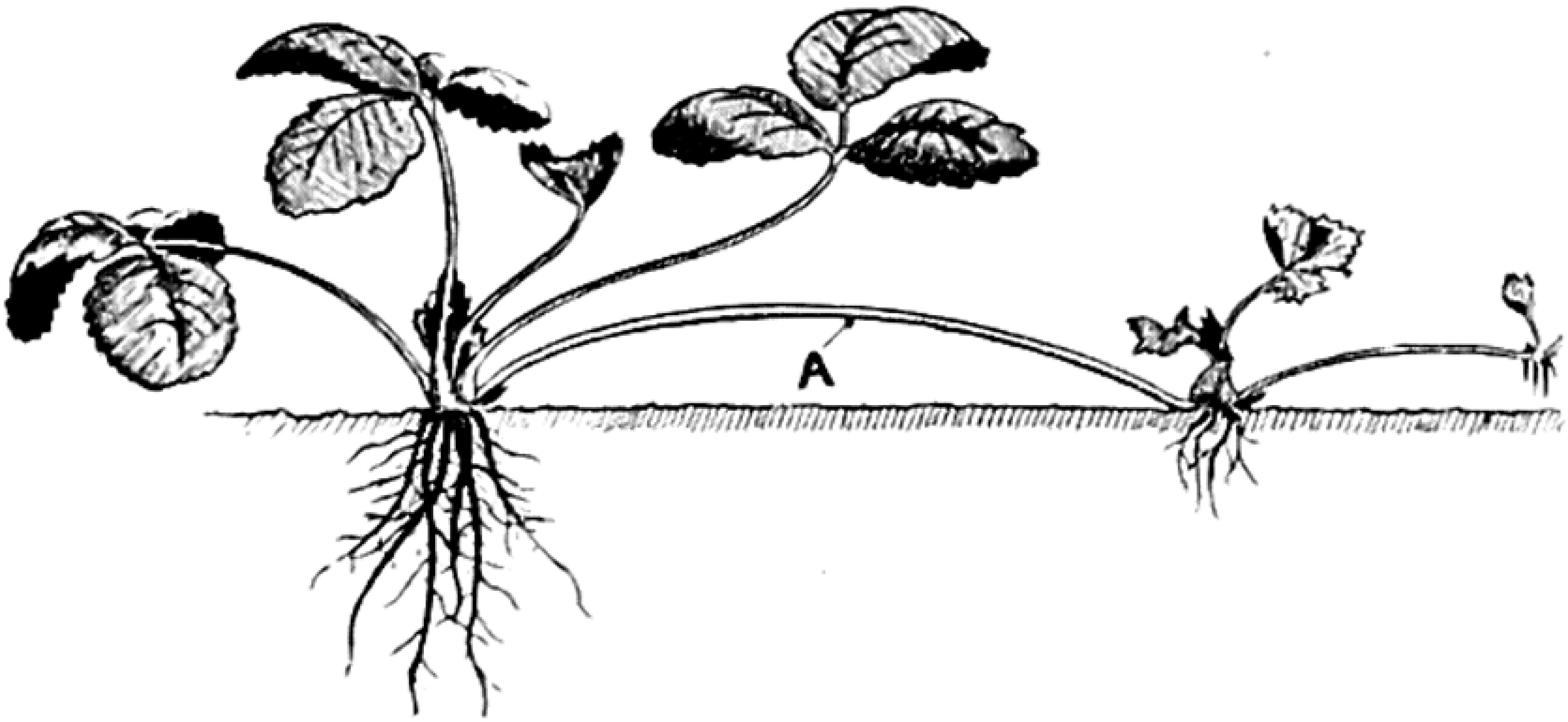
# 7

# The Work and Growth of Plant Stems

Yet nature is made better by no mean
But nature makes that mean; so over that art,
Which you say adds to nature, is an art
That nature makes. You see, sweet maid, we marry
A gentler scion to the wildest stock,
And make conceive a bark of baser kind
By bud of nobler race. This is an art
Which does mend nature—change it rather; but
The art itself is nature.

*A Winter's Tale* (SHAKESPEARE).

YOU HAVE learnt a good deal about the roots, leaves, and flowers of green plants; let us now find out more about plant stems. You will find them in great variety as you look around the fields and gardens—the firm branches of trees, the trailing runners of strawberry plants, the straggling tentacles of scrambling plants like cleavers, and countless others: all are stems, and whatever their shape or form most stems serve as connecting channels between the roots of the plant at one end and the leaves or flowers at the other. A little thought will remind you that plants have two entirely different sorts of solution moving about inside them. The solutions of plant *nutrients* from the soil have to be transported from the roots upwards to the leaves; and the various sugars and protein substances that are created in the leaves have to be moved downwards from the leaves to other parts of the plant in order that further growth of roots and so on may take place. There is, you see, a two-way traffic of entirely different substances, and whatever other *functions* the various kinds of stem may have, all ordinary stems do serve as the conveyors of these liquids. This is not quite true of highly specialized stems like potato tubers and crocus corms, which have been specially *adapted* as storage organs, but all normal stems are, first and foremost, the food channels of the green plant.



The stems of most plants grow skywards, but this strawberry runner (A) is a stem that grows sideways. Can you think why?

## THE INSIDE STRUCTURE OF STEMS

It is, of course, important that these two different sorts of liquid should not get mixed up, otherwise some of the various materials would be transported in the wrong directions. There *must* be an arrangement inside the stem to ensure that the solution absorbed by the roots and the sugary solutions created in the leaves are kept separate. The following experiment will show us that such an arrangement does indeed exist.

*Experiment 1. To trace the track of soil solutions inside plant stems.* You need to repeat the experiment you did with woody twigs when you were studying Chapter 3 in Book III. This time, however, you must observe the cut section of your twig more carefully—and a small magnifying glass will help. The red ink acts as a *tracer* of the soil solutions, and an exact examination of the cut surface of your twig will show you that these solutions have not travelled up all parts of the stem—only certain parts are stained with the ink; and you will find that in a very young shoot the soil moisture travels up a number of channels that, in your section, look like a circle of red dots. In an older twig, however, these channels are all connected to form a cylinder of tissue up which the soil solutions are conveyed. If your twig is sufficiently developed, the red stain will take the form of a complete ring lying just beneath the so-called bark of the stem. There is no staining in the bark itself, nor is the central portion of the twig stained. You have shown quite conclusively that inside the stems of green plants there is a special channel up which the soil solutions are passed.

We give a special name to the tissue that conducts these upward moving liquids—we call it the XYLEM or, more simply, the *wood*! There is, you see, a certain amount of wood even in soft-stemmed annual plants like the groundsel; but there is, as you know, a good deal more wood in the trunks and branches of trees and shrubs. In the case of most big trees, however, only the outer layers of the wood are used as conducting channels: the mature inner wood has long

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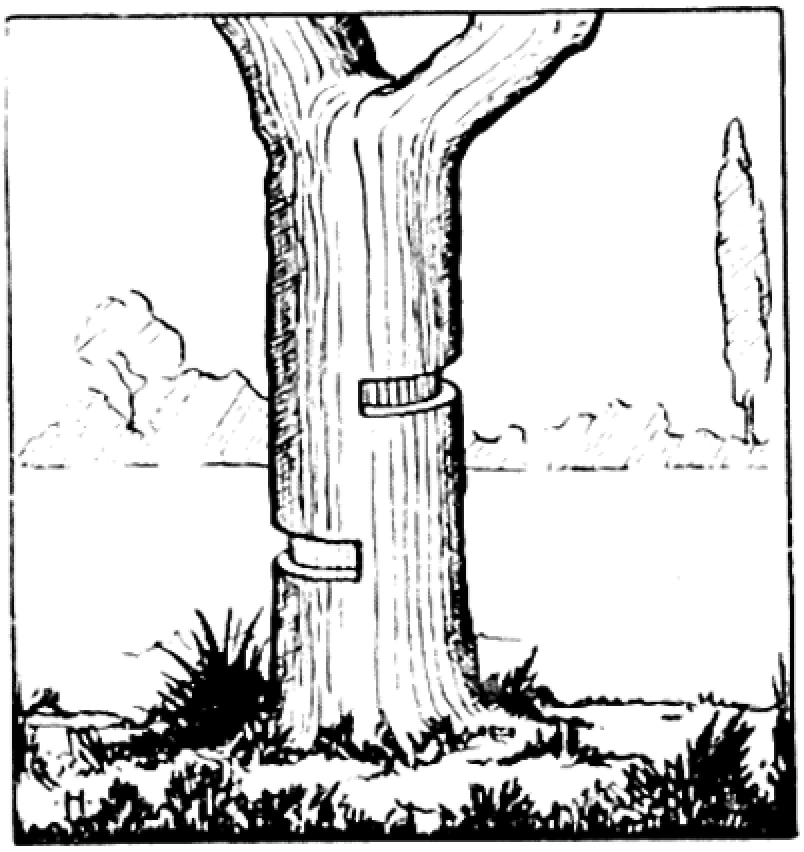
[1] Pronounced 'zylem.'

been out of action—it serves only as a supporting skeleton and the tissues of this *heartwood*, as it is called, are quite lifeless. The outer layers up which moisture is conveyed are called the *sapwood*—and this sapwood is the part of the timber that is not so useful to carpenters and joiners as the heartwood; the latter, as a rule, is harder and more durable.

It is quite easy to peel a young twig—the outer layer comes away very easily and it is separated from the wood core by a layer of moist, slippery material. We often call this peel the 'bark,' but it is composed, not only of protective bark: it contains also the channels down which the leaf solutions of sugar and so on are conveyed to the roots and other underground parts of the plant. There is no simple experiment that will enable you to prove this, but we know that it is so because of *elaborate* experiments that have been carried out by clever *research* workers in the universities. There is, however, a roundabout way of coming to a similar conclusion—of showing that this so-called bark is more than just a protecting layer. You have perhaps seen what happens to a young fruit-tree when the bark all round its main stem has been nibbled off or *girdled* by rabbits. If this girdling of the bark is very extensive, the tree eventually dies; not because of the exposure of the inner layers to the weather, but because the food channels between the leaves and the roots have been severed! In such a case no further root development can take place, and although life may continue for some time, the tree does finally perish. The young forest trees of new plantations often suffer considerable damage in this way from rabbits; that is why these creatures are such a pest to the forester. The beautiful red squirrel is at times an offender in this respect, but these agile and lovely animals are not numerous enough to be regarded as a pest. They have been driven out of many parts of Britain by that rather less attractive alien, the grey squirrel, and the red squirrel is nowhere as commonly seen as we should like it to be.



What effect does the gardener hope to produce when he girdles his trees in this way?

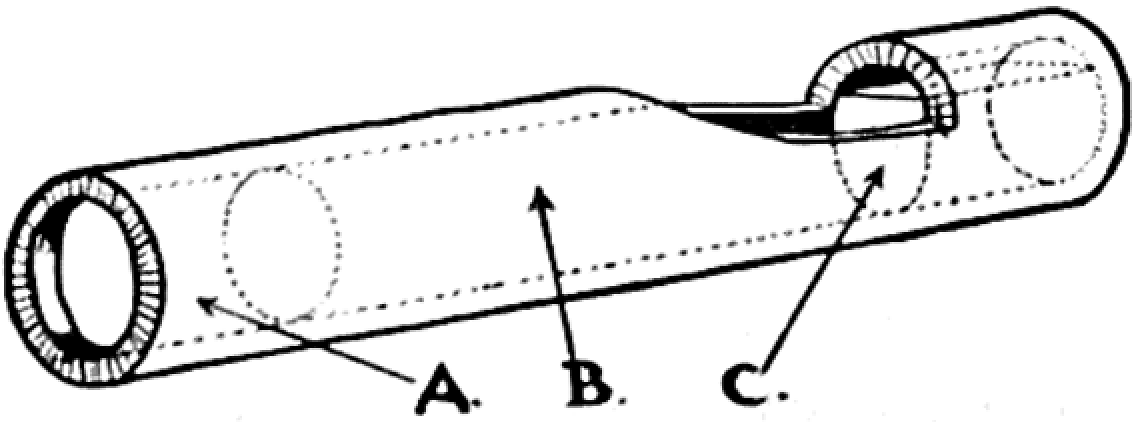
Sometimes the fruit-grower girdles his trees in order to make them fruit more abundantly. He calls the operation *bark-ringing*, but he always takes care to make only a very narrow groove—about a quarter of an inch wide—round the tree and the cut is soon healed over. Sometimes two half-rings are removed, one above the other as shown in the accompanying drawing; and in this case the grooves may be as much as half an inch wide.

### A SIMPLE TOY

If you have a young brother you can quite easily make him a simple whistle from a young twig, and you will at the same time impress these new facts about stems more firmly on your memory. Books certainly help us to learn, but you should lose no opportunity of seeing things for yourself.

In order to make this toy you need a really sharp knife and a short length of twig cut from a fast-growing tree like the lime or the horse-chestnut. The stem you choose should be two or three years old so that it has a good core of wood inside the bark, and you should select a straight piece about three inches long that is free from buds and side shoots. Spring is the time for the job, because at that time the layer of tissue between the wood and the bark is quite soft—which is just what you want.

First of all, tidy up the two ends of your stem with clean, straight cuts; and then, using a small stone or the haft of your knife, tap the bark firmly all over for a few minutes. This bruises the layer between the wood and the bark, and before long you will be able to slip the wooden core of the twig out of the enclosing cylinder. Replace the bark cylinder and make two more clean cuts so as to remove a notch as shown below. Your whistle is now almost complete. All that is necessary is to remove the core of wood again and cut two small plugs from it—one for each end of the cylinder of peel. Replace one of these at the bottom end of the whistle and, after cutting a thin slice from the other, push it



You can make this whistle in a few minutes if you use a sharp pen-knife, some care, and a suitable twig. A and C show the wooden plugs and B shows the hollow space.

back into the end near the notch. The thin slice that you cut from this piece leaves a slot that enables you to blow the whistle you have made.

## HOW TO TELL THE AGE OF TWIGS AND SMALL BRANCHES

You have learnt[1] that the new twigs that trees produce each year are extended to their full length in the season of their origin. They increase their girth in following years, but not their length. This manner of growth enables us to estimate quite accurately the ages of the various parts of a small branch, because careful observation will enable us to see where each year's growth began.

As you know, the buds from which new shoots arise are covered with numerous scales that have been protecting the tender parts inside all through the winter. When the buds open in spring these scales fall to the ground and they leave behind them on the twig a ring of scars. Each time a new shoot is produced, a ring of these scars appears at its base, and as these scars remain visible on the stems for many years, they enable us to trace the age of any part of a small branch.

The accompanying drawing of a sycamore branchlet shows that it started life four years before it was broken from the tree. The outermost shoots are the most recent and are almost a year old. Notice the scar girdle at the base of each of these new shoots. Now trace downwards along all the shoots until you come to the next series of scar girdles. The portions of the young branch that appear between the first and the second girdles of bud scars are two years old and so on.

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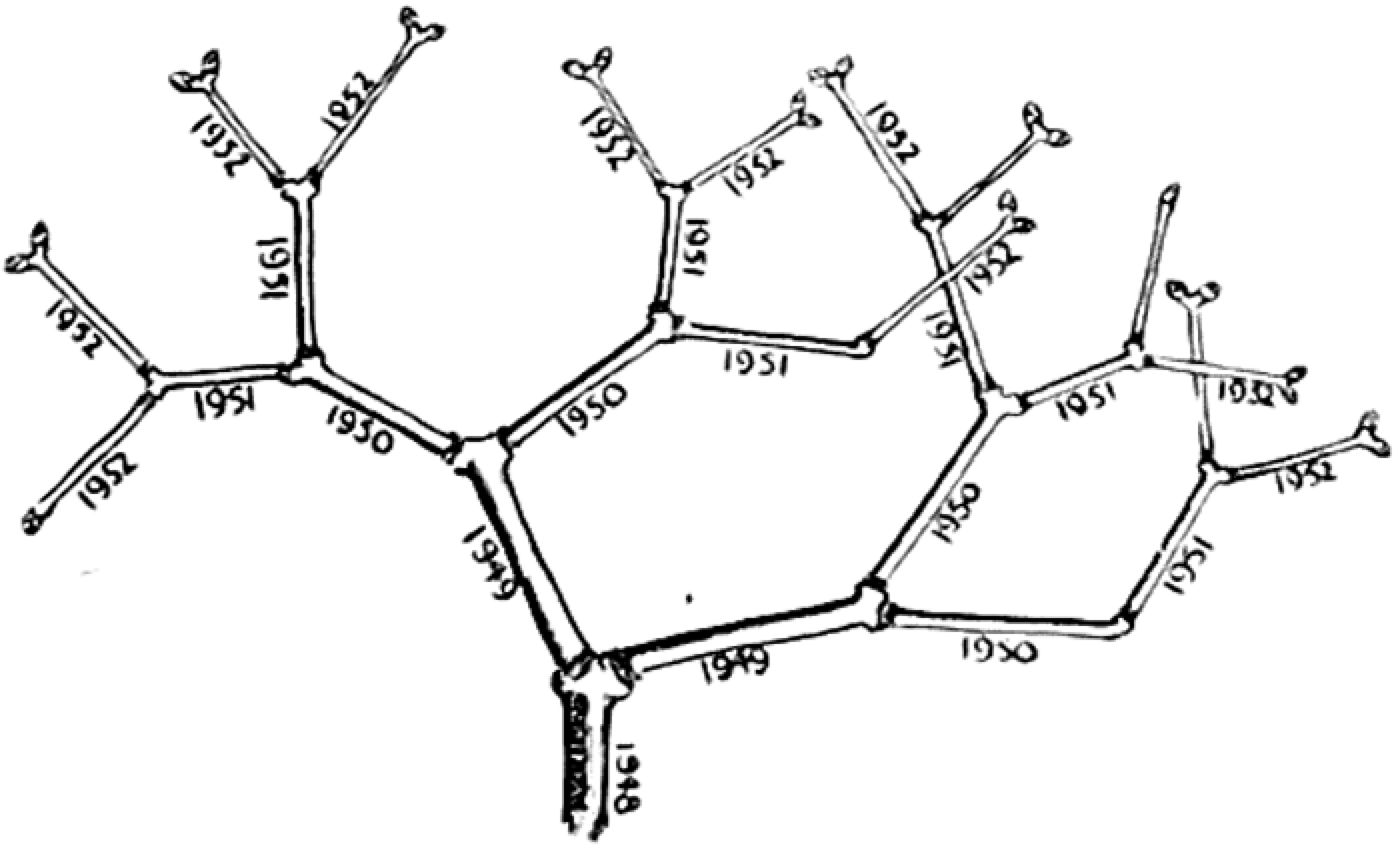
[1] *Rural Studies*, Book III, Chapter 1.

It is often possible to trace backwards in this way for twenty years or more, and if you choose a specimen for yourself you will no doubt be able to point out the parts of the branch that were young new shoots in the year of your birth. Quite often too it is possible to notice the different effect on growth of the varieties of weather over a number of years. Those sections of your branch that were produced in good growing years—when the summers were both damp and warm—are often quite long, whereas the poor summers are usually recorded by only a short growth. Indeed the weather has written its own diary on the branch that you hold in your hand.



The traces left by former buds enable us to put an accurate date on each section of this sycamore branchlet. Pick out these old scars and draw the young branchlet as it appeared in the winter, (*a*) of 1948 and (*b*) of 1950.

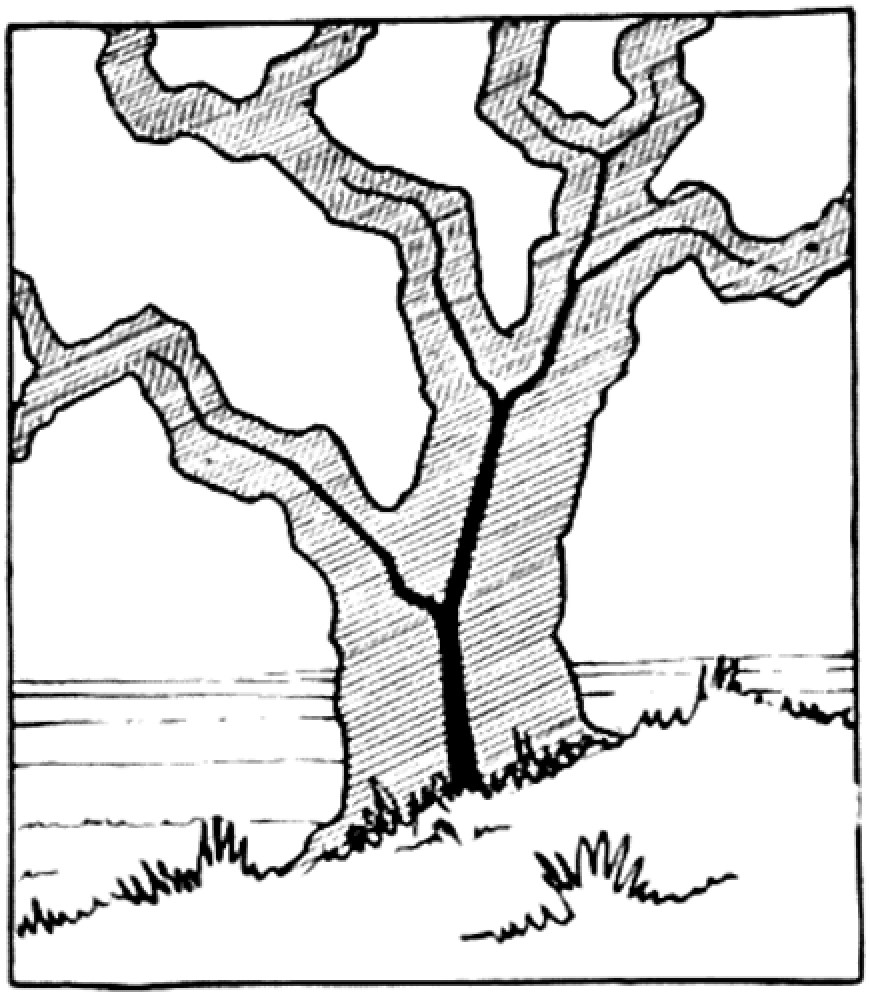
If you cut across the various portions of these twigs, you can check the accuracy of your calculations by counting the number of rings in the wood. Sections that are one year old have a single core of wood;

those that are two years old have an added ring, and so on. You will find moreover that these annual rings usually vary in thickness from season to season just as the shoots varied in length. Checking the life and age of tree stems in this way is a fascinating pastime and you should try it out for yourself. Bear in mind that only the woody perennials can be dated in this way. Other plants—herbaceous perennials like the lupin, biennials like the foxglove, and annuals like shepherd's-purse—lose their stems before these woody developments can take place.

## THE SHAPE OF A TREE

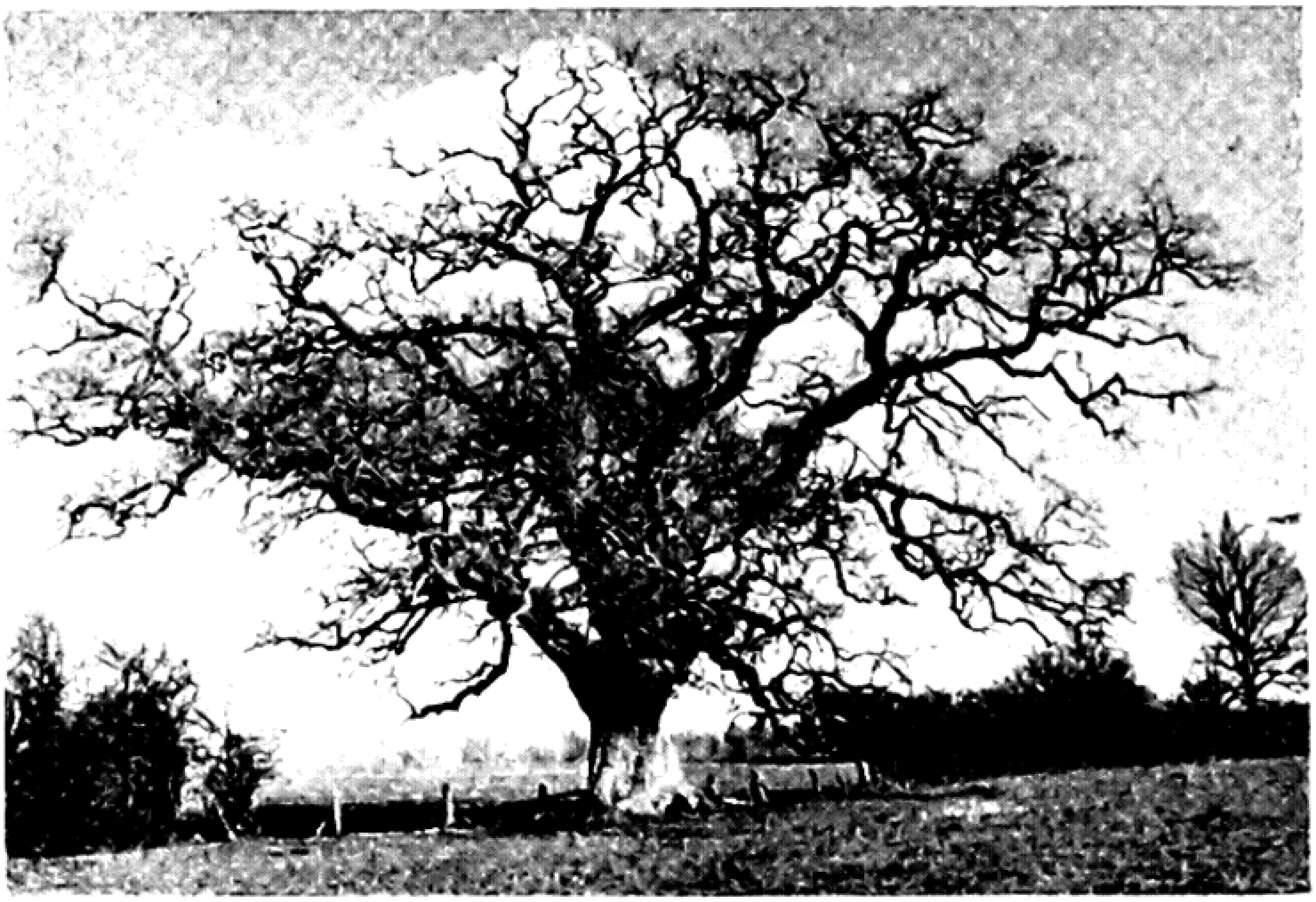
All our forest trees have a distinctive shape which enables us after a good deal of practice to recognize many of them from a distance without having to examine their leaves, buds, and so forth. Each tree owes its individual shape to its manner of branching. Thus the beech has long *sinuous* branches—the outermost ones often having the appearance of great plumes; and the rugged elbows and the twisted branches of the oak are familiar to every one. The sycamore has a framework of branches that is quite different from either beech or oak: its outermost twigs have the appearance of delicate lacework.

If you bear in mind that all these branches have been built up by a succession of shoots, you will easily understand that the distinctive branching of each kind of tree can be traced back to the particular way in which the twigs have developed. Let us gather specimens of the young twigs of beech, oak, and sycamore and examine them carefully. You will see that each shoot bears buds in two positions: there are *lateral* buds on the sides of the twigs and there is a *terminal* bud at the end. Not all these buds develop each year—there would not be room for all the new young shoots if they did; many of the buds either die off or remain dormant. *It is clear, however, that the characteristic shape of each tree will depend on which buds develop to produce the new shoots*, and it will depend also on the lengths of these various shoots. Let us examine the beech branch first. You will soon see that the terminal bud always produces a much longer shoot than the lateral buds, with the result that many short twigs are found growing on the long, whip-like main stem. This manner of growth gives to the beech its graceful, feathery appearance.



Buried in the limbs of every great tree lie the twigs that decided its shape.

To what does the oak-tree owe its angular growth? If you look at the younger twigs on your oak branch you will find that the terminal bud is surrounded by a small group of lateral buds. What would happen if the terminal bud failed to produce a shoot? One of the lateral buds would develop instead and an elbow would be formed because the new shoot would come off at an angle. This is what does often happen in the case of the oak, and the angular appearance of many of its branches is the result. Big things, you see, have small beginnings. You would never suspect that the gaunt and rugged shape of Britain's oak-trees was due to the way in which their buds develop; but this indeed is the truth of the matter. You will find that the characteristic growth of the sycamore, and indeed of all trees, can be traced to the same source, and you should make similar examinations of other trees and of their twigs for yourself. Try to account for the shapes of the horse-chestnut and the silver birch.



What caused the bends in the elbowed limbs of this rugged oak?

### THE PRUNING OF YOUNG APPLE-TREES

The most suitable apple-trees for small gardens are known as bush trees, because they do not have a tall trunk and they can be grown in a small space. Every good gardener likes to buy these bush apple-trees when they are only one year old. At this stage they consist only of a root system, together with one straight stem about two feet high on which there are a few short lateral twigs. At this stage they are called *maiden trees.* If these maiden trees were allowed to develop on their own they would, of course, grow into fine big specimens, but long experience has shown us that better results are obtained if their shape is controlled; not only do they take up less space if this is done, they also produce better crops of apples. Your study of the young twigs of forest trees will enable you to understand how the fruit gardener sets about 'training' his trees. You already know enough to realize that a few buds destroyed in any one year will alter the future shape of the tree entirely. The gardener knows this also, and he is well aware that he can himself control the shape of his growing fruit-trees by skilful pruning in the first three or four years of their lives. He likes to start this job from the beginning and that is why he likes to buy maiden trees. Remember what this early pruning does—*it ensures the development of chosen buds each year and so determines the final shape of the tree.*

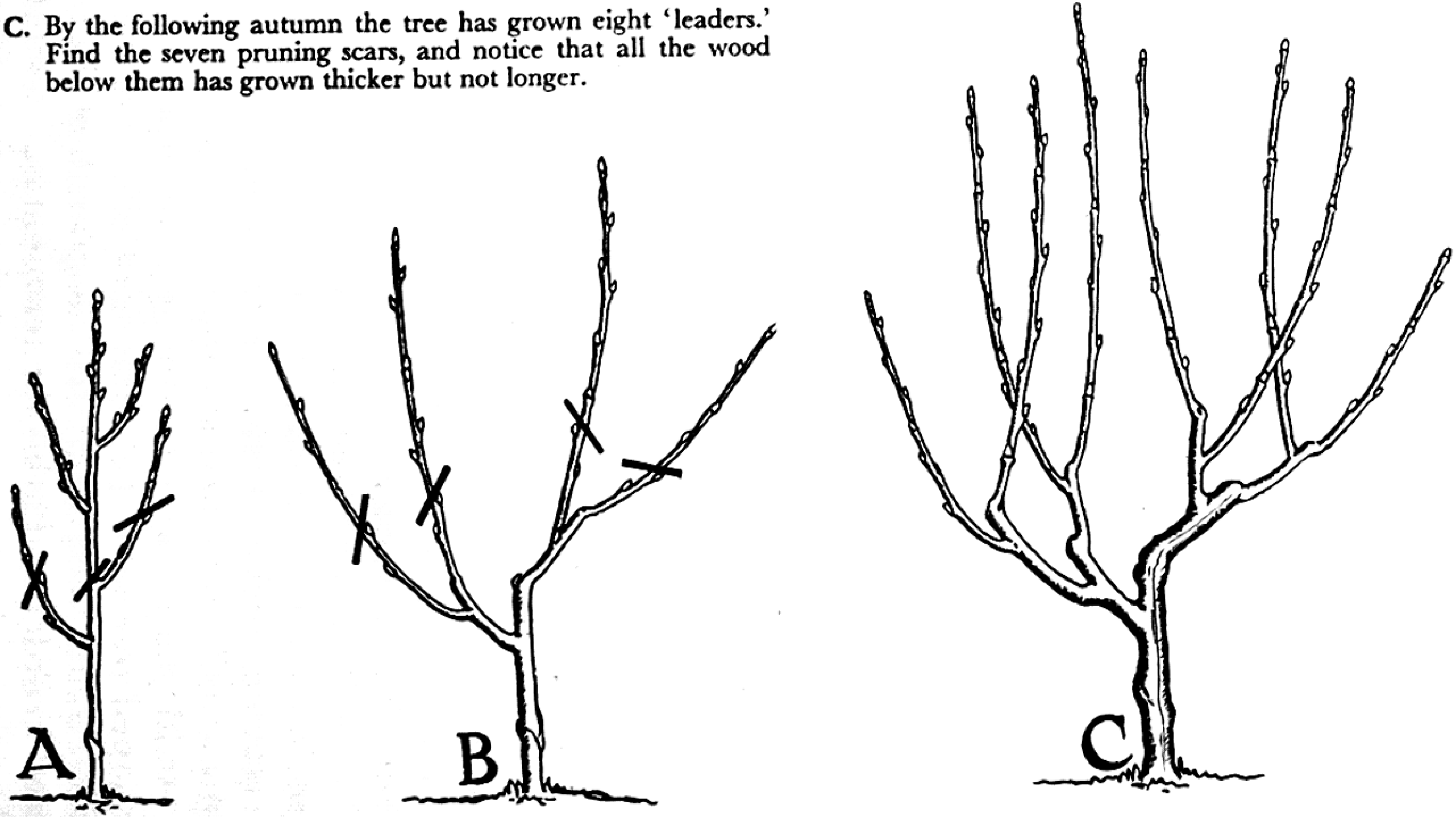
The ideal bush tree consists of about eight or twelve main branches arising from a short trunk about eighteen inches high. Now, supposing you were presented with a maiden apple-tree one autumn—how would you set about pruning it to produce a goblet-shaped tree with the number of branches mentioned? You would need to *stimulate* the growth of *side* branches, and in order to do this the terminal bud would have to be removed so as to prevent the continued growth of

These three drawings of *the same* apple-tree show you how to control the shape of a young tree as it grows.

**A.** In its first autumn this maiden tree was pruned by three cuts, and only four buds were left to grow.

**B.** One year later the four buds have grown four shoots. Find the three scars left where the maiden tree was pruned. Notice also the thickened 'trunk,' and the four new pruning cuts.

**C.** By the following autumn the tree has grown eight 'leaders.' Find the seven pruning scars, and notice that all the wood below them has grown thicker but not longer.



the central stem. The removal of this bud would have the effect of causing numerous lateral buds to develop into side branches. In order to confine these side branches to a short trunk you would have to cut off not only the terminal bud but also all the main stem at a point eighteen inches or so above the soil; and as you see at **A**, any side growths left on this central stem would also need cutting back so as to ensure a compact 'footing' for the tree. In the following summer some three or four side branches would grow from this 'footing'; and each of these would need to be pruned back after the leaf fall to a bud about half-way along its length (**B**). After the second summer (**C**) you would see your tree beginning to take its goblet shape—there would be some seven or eight small branches on a sturdy base. Perhaps you might consider that you now had enough *leaders* as these young branches are called. If so your main pruning for shape in the following years would consist in removing the top two or three inches of each year's growth on the leaders in order to prevent them shooting skywards and making your tree too tall. There would be some other pruning to be done also in *subsequent* years, but it is enough for you to learn at present how a knowledge of the growth of trees does enable us to produce almost any shape of tree we want.

## HOW MAIDEN APPLE-TREES ARE PRODUCED

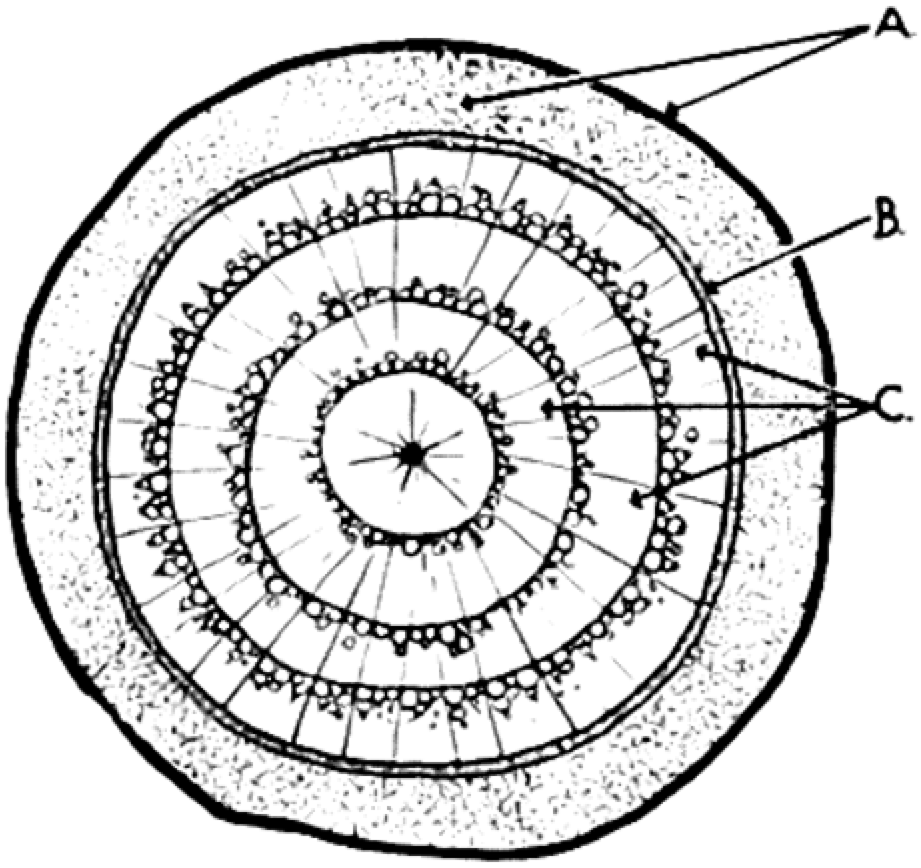
Maiden apple-trees and maiden pear-trees are not usually produced from seeds, because, as you learnt on page 148, it is not possible to guarantee that a pip will 'come true to variety' as the gardener puts it. The apple seed would most certainly develop into a tree, but nobody would be able to forecast what kind of apples this new tree would produce. You might like to try this for yourself. It will take several years before you get your new apples, but you may find that you have discovered a splendid new variety. That, of course, is exactly how many sorts of apples and pears did originate.

This method of raising new trees is no use to the gardener, however; he wishes to be able to name his maiden trees with certainty. Instead, therefore, of sowing apple pips he makes use of a vegetative process called *grafting*—and a second advantage of this method is that grafted trees produce fruit much sooner than trees grown from seed.

## WHAT MAKES GRAFTING POSSIBLE?

In order to understand what grafting is and why it can be done, you will need to think again about a young woody twig. You will remember that in between the bark and the woody core there is a layer of tissue that becomes quite slippery when it is bruised. It was this slippery layer that enabled you to slip the bark cylinder off the woody twig when you were making the toy whistle. Now this layer of sappy tissue is very important indeed—it is called the **cambium** layer, and the girth growth of the tree depends entirely upon it, because it is this layer that produces both the new ring of wood each year and also the tubes in the bark down which the leaf solutions are passed to the root.

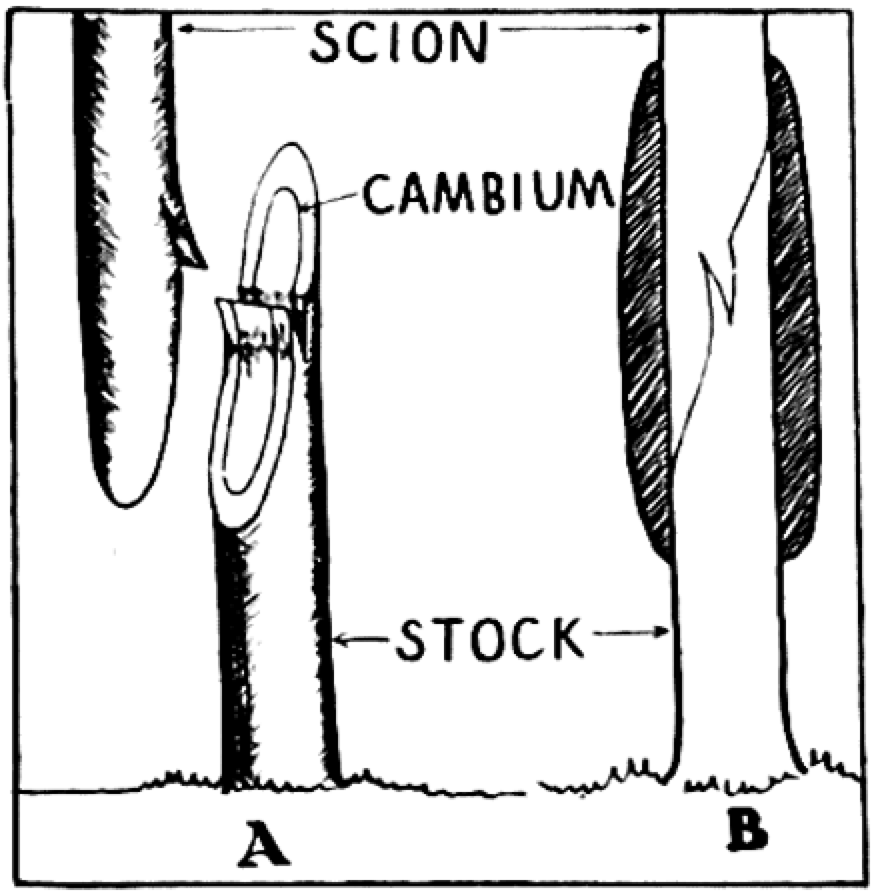
Have you ever noticed what happens when a small tree branch is sawn off near the trunk? A layer of new tissue is produced to heal the wound, and in many cases this **callus**, as it is called, completely covers the saw cut. *This callus is produced by the cambium layer*—and whenever the bark of a living twig is damaged, the underlying cambium produces callus in an attempt to weld the severed parts together. It is this remarkable activity of the cambium layer that makes grafting possible. If a young apple shoot is cut from a tree and inserted beneath the bark of any apple branch, so that the cambium layers of both the shoot and the branch are held in close contact, callus will fuse the parts together and the twig will become 'part and parcel' of the branch—continuing to flourish in its new position as if it had always grown there. All our fruit-trees have a cambium layer, of course, but the *fusion* you have just read about will not take place unless the twig—or **scion**, as it is called—is grafted on to a closely related tree or **rootstock**. Apple scions can be grafted on to apple or crab rootstocks, pear scions on to pear or quince rootstocks, and so on.



Here is the magnified cross-section of a lime-tree twig. At A you see the 'peel,' B indicates the important *cambium*, and C shows the rings of xylem or wood. How old is the twig?

## WHIP-AND-TONGUE GRAFTING

The grafting of scions is carried out in spring just as the sap is rising. For producing maiden apple-trees, special apple rootstocks called *Malling*[1] stocks are usually used and the rootstock should be at least two years old—that is to say, it should have at least one ring of wood round the woody core. It is best to use rootstocks that are no older than this, as the whip-and-tongue method of grafting about to be described is easier to work when the stock and scion are of similar diameters. Such a rootstock consists of a single main stem on a well-developed root; and when the grafting is to be done this main stem is cut off, with a very sharp knife, three or four inches above the soil. The cut should be long and slanting so as to expose plenty of cambium.



A simple whip-and-tongue graft. Why are the grafting surfaces notched with a second cut?

A good scion needs careful selection. Long, sturdy shoots of *new* wood are cut from the chosen apple-tree in the previous autumn—after the fall of the leaves. These are heeled into a cool, moist corner of the garden; and when grafting time arrives the thick, ripe portions of these 'prunings' are cut into lengths each of which carries about four buds. These lengths of apple wood are your scions, and if you want to make a good graft choose a really solid scion for your work.

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[1] These may from time to time be had from The East Malling Research Station, East Malling, Kent.

Taper your selected scion *at its bottom end* so that it will fit neatly on to the prepared stock. If you make a further small cut on each of the slanting surfaces, the scion and stock will fit snugly together as you see in the drawing, and you will have both hands free to finish the job. Tie the junction firmly with raffia, cover it with grafting wax to protect it from the weather, and the operation is complete.[1]

There are several other ways of making the cuts which you can learn from gardeners or from books on the subject, but whatever method is used, the important thing is to get as much contact between the cambium layers as possible—these are the layers, remember, that will cause the fusion. If you have no fruit-stocks to experiment upon in the garden, you can cut twigs from any kind of tree and move them to other small branches on the same tree quite easily. Lime and horse-chestnut are perhaps the best for beginners because they have good stout twigs and they are easy to cut. Lime is particularly easy to work, and it will most certainly provide you with successful grafts.

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[1] **Black insulating tape makes a very effective substitute for raffia and grafting wax.**

**The scion buds will throw several shoots during the summer; and if, in the early autumn, you remove all but the strongest one of these, a flourishing maiden tree will develop in the following year.**

## THINGS TO DO

(1) Write a short composition entitled 'Two Kinds of Liquid in Plant Stems.'

(2) Write complete sentences in answer to the following:

- (*a*) What do we call the stem tissue up which soil solutions are passed?
- (*b*) Down what part of tree stems are the leaf solutions transported?
- (*c*) What is the name of the soft layer of tissue just beneath the bark of trees?
- (*d*) How can you tell where one year's growth of a small branch begins and ends?
- (*e*) What is the cause of the elbows on oak-tree branches?
- (*f*) What is a terminal bud?
- (*g*) Why do gardeners prune young apple-trees?
- (*h*) Why are apple-trees rarely grown from pips?

(3) Select a small branch from any forest tree. The thick end should be no wider than your little finger. Remove the leaves and draw it carefully, showing where the bud scars are to be seen. Now date the various parts of your branchlet by writing the year of their growth alongside them.

(4) Make clean cuts across several parts of the branch you used for the above diagram and make drawings of the annual rings you see. The drawings should be made much larger than the real thing—about as big as a penny.

(5) Make a collection of different kinds of stems and bring them to school for exhibition. You should include a tree twig, a wheat straw, a potato, a couch-grass rhizome, and things of that kind. The whole class should make a collection of at least twenty different *sorts* of stem—not just stems of different plants.

# 8

# Water

And on a May mornynge · on Malverne hilles,
A wondrous thing byfel me · of fairy, methoughte;
I was weary with wandering · and wente me to reste
Under a brode bank · by a burnes side,
And as I lay and listened · and loked in the wateres,
I slombred in a slepyng · it sounded so merye.

*Piers the Plowman* (WILLIAM LANGLAND, *c.* 1332–*c.* 1400).

## WHAT IS WATER?

WHEN the *composition* of various substances is under examination we say that their chemistry is being studied. You are now going to find out something about the chemistry of water: that is to say, you are going to find out the substances of which it is composed. You have already [1] made a study of the chemistry of the gas carbon dioxide and you know that it is composed of carbon and oxygen. Sugar, also, you have examined [2] and you know that it contains carbon and that it produces water when it is burned. Substances that are made up of two or more other substances in this way are called *compounds* by the chemist. Thus sugar is a compound, so is carbon dioxide. Oxygen, however, cannot be split up into any other substances and for this reason we call it an *element*. What about water? Is it a simple element that cannot be split up or is it a compound? And if it is a compound, of what other materials is it composed?

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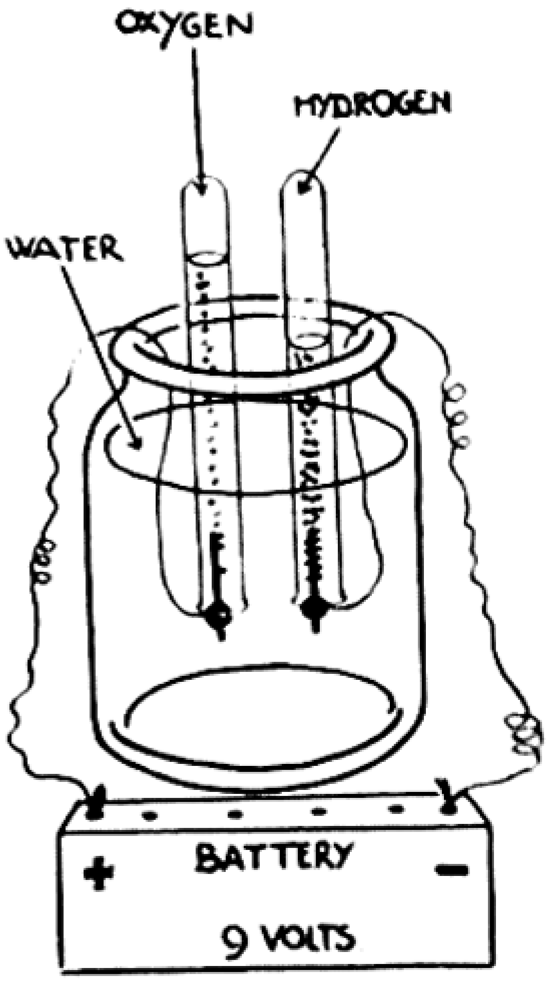
[1] *Rural Studies*, Book II, Chapter 2.

[2] *Rural Studies*, Book II, Chapter 6.

The following experiment will show you that water is a compound. The simplest way of splitting it up into its *constituents* is by passing an electric current through it, which is what you are required to do.

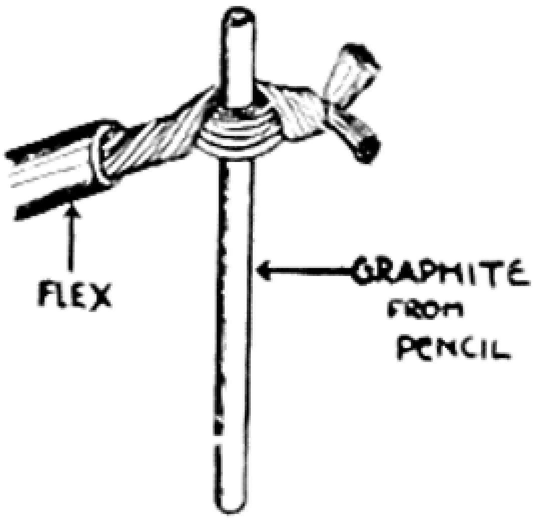
## THE ELECTROLYSIS OF WATER

*Experiment 1.* You will need the following materials: a 1-lb. jam-jar, two circular 1-oz. bottles such as can be got from the chemist, two 12-inch lengths of rubber-covered wire from a piece of flex, 1 oz. of dilute sulphuric acid, a new 'grid-bias' dry battery (9 volts or more) which can be got from the radio dealers for about 1*s.* 6*d.*, and two pieces of graphite (a form of carbon) taken from a pencil; each piece of graphite needs to be about an inch and a half long. In addition you will require some candle wax or a small quantity of plasticine.



*Experiment 1.* The electrolysis of water.

Let us prepare the electrical apparatus first. Take your two lengths of rubber-covered wire, and from both ends of each piece remove about one inch of the covering so as to expose the wires inside. Your battery contains a series of plug-holes, and you will need to insert one exposed end of each of your two cables into the two plug-holes that are furthest apart—one at one end of the battery and one at the opposite end. In order to obtain a good electrical contact you should twist the wire that is to be inserted, bend it double, and twist it again so that it plugs *firmly* into the hole in the battery. Do this with each piece of cable. When you have done so, each cable will have one end attached to the battery and one free end of exposed wire. To each free end attach a piece of the graphite; and then, either by dipping the free ends into molten wax or by encasing them in plasticine, cover any exposed wire so that when the two carbon *electrodes* are placed in water, the wires themselves do not get wet. Take care, however, to leave at least an inch of each graphite stick fully exposed.



A firm twist of the wire will secure your graphite electrodes.

Now pour your ounce of *dilute* sulphuric acid into the jar and add water until the jar is about three parts full of liquid. The two small bottles (two test-tubes or two specimen-tubes would serve quite well instead) must be filled with water, inverted, and placed with their mouths about an inch beneath the surface of the liquid in the jar. Keep a finger over the mouth of each bottle while you do this so as to keep it quite full of water. The bottles can be held in position by means of a thin stick of wood that is placed across the top of the jar. Each inverted bottle can be fixed firmly to this with an elastic band or a length of thin wire.

You are now ready to begin. Carefully insert your two electrodes into the *acidulated* water and fix them up inside the necks of the two bottles. You will be surprised at what happens. As soon as the carbon electrodes get into the liquid, bubbles of gas begin to rise from them, and this gas will collect inside the bottles. It will take half an hour or so for one of the bottles to fill, but you should watch the experiment carefully during this time. You will find that much more gas is coming from one electrode than from the other—indeed *exactly* twice as much. Your apparatus will not measure the quantities accurately, but as time proceeds you will be able to see that the volumes of gas are delivered into the two bottles in about the proportion of two to one. Notice also that the electrodes are not being used up. The gases are not coming from them. No matter how long the experiment is allowed to continue, those pieces of carbon will remain exactly the same size. Nor are the gases coming from the sulphuric acid that is dissolved in the water. Tests would show us quite clearly that none of the acid is used up. Indeed the only reason for putting the acid in was to enable the electric current to flow freely through the water from one electrode to another. It serves merely to conduct the electricity, *pure* water being a poor conductor. Where then are these gases coming from?

They are coming from the water itself; the electric current is splitting the water into its components. We call this process **the electrolysis of water,** and when the bottles are full we shall be able to test the two gases into which the water is being split up so as to identify them. When the first bottle is ready it can be removed and tested while the other continues to fill.

Before removing the bottle from the water, seal it with your finger so as to prevent the escape of the gas it contains. When you have taken it out of the jar hold it mouth downwards, light a match or a taper, and then, removing your finger from the inverted bottle, apply the light to its mouth. Watch carefully to see what happens. The gas inside is inflammable; it burns with a clear bluish flame. You have proved that **one of the ingredients of water is an inflammable gas.** This gas is an element and we call it **hydrogen.**

When the other bottle is full or almost full remove it in a similar manner. This time, however, you can keep the mouth of the bottle upwards. (The reason for holding the other bottle upside-down was in order to prevent the hydrogen from escaping when you removed your finger. Hydrogen is much less dense than air[1] and it escapes upwards very quickly.) Prepare a glowing splinter and plunge it into the second bottle as soon as you remove your finger. The glowing splinter bursts into flame immediately. Can you guess what this gas is? **The second ingredient of water is the gas oxygen.**

This is rather a surprising result. You have discovered that water is made up of two gases—hydrogen and oxygen—in the proportion of two volumes of hydrogen to one volume of oxygen. Chemistry expresses this by giving to water the formula $\mathbf{H_2O}$, the letters standing for the two substances of which it is a compound—**H** for hydrogen and **O** for oxygen; and the figure 2 informs us that two volumes of hydrogen combine with one volume of oxygen to form water. Perhaps you have heard the expression $H_2O$ before? You now know, from your own experiment, something of what the expression really means.

If water can be split up into hydrogen and oxygen in this way, it ought to be possible to build it up again from these two gases. Indeed that is exactly what happens when hydrogen burns. During the burning process the hydrogen combines with some of the oxygen in the atmosphere and water is formed. Let us prepare some hydrogen in order to demonstrate the formation of water when we burn it.

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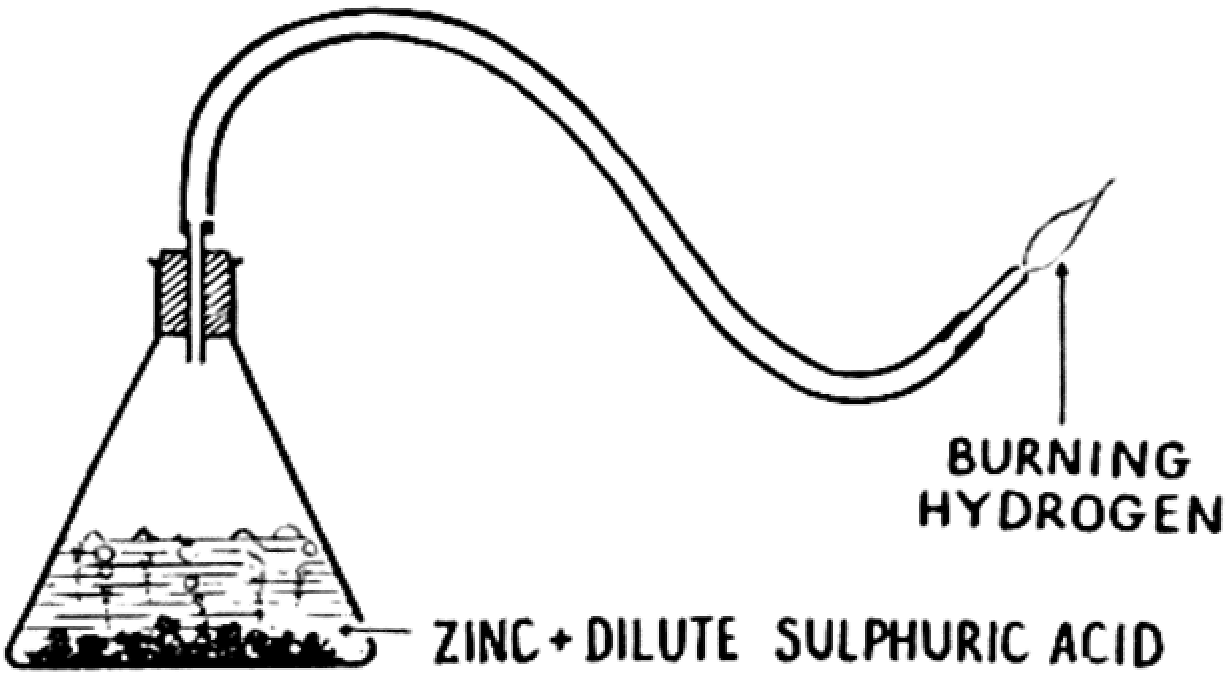
[1] This means that a volume of hydrogen is lighter than a similar volume of air.

### THE PREPARATION OF HYDROGEN

*Experiment 2.* You will need either a special glass flask or a bottle such as a mineral-water bottle, together with a cork to fit it tightly. Bore a hole through the cork either with a red-hot knitting-needle or with a cork borer. Make the hole big enough to receive a 3-inch length of ¼-inch metal tubing, such as motor engineers use for petrol piping. Take care, however, not to make the hole too big—it should allow the tubing to fit snugly so as to avoid the escape of the hydrogen you are going to make. In addition you will need about a tablespoonful of either granulated zinc, which the chemist can get for you, or a similar weight of thin iron wire, together with about half a pint (8 oz.) of dilute sulphuric acid.

You will also need about 12 inches of rubber tubing that will just fit the metal pipe in the cork—and a second short length of metal piping (about 2 inches long) that has been hammered at one end so as to provide a jet for burning the hydrogen. The jet should be big enough to receive a small pin, no bigger. Lastly you will need a fairly big metal can that is *water-tight*. A large-size can that has contained tinned fruit would serve very well, but its exterior must be of bright metal—there must be no paint or varnish on it.

Half fill the bottle or flask with the dilute sulphuric acid and then add the iron wire or the zinc. Bubbles of hydrogen will begin to be produced immediately—the action of the metal drives the gas out of the sulphuric acid which contains a great deal of it. Now place your piece of metal piping into the bored cork and replace the cork in the bottle. Attach the metal jet to the other end of the rubber tube and all is ready. You must on no account light the jet of hydrogen for at least five minutes, however. *All* the air that was in the bottle has to be driven out first or there is danger of an explosion. For the same reason there must be no naked flame about while the apparatus is being set up. But at the end of five minutes all will be safe and you can put a match to the jet of hydrogen. If the hole is a suitable size, the flame of burning hydrogen will be from ½ inch to 1 inch long.



*Experiment 2.*
The preparation of hydrogen.

### THE PREPARATION OF WATER

The burning hydrogen can be seen quite clearly but there is no sign of any water. The water is, however, being formed; but the heat of the flame causes it to remain in the form of a vapour—water vapour. Fill the bright metal fruit tin with cold water, taking care to keep the outside of the tin quite dry, and play the flame on to the cold surface of the metal. This will cause the water formed by the combustion of the hydrogen to condense and the part of the tin on to which you direct the flame rapidly becomes quite wet. If you can support the jet and the tin in some way, and leave the experiment running for a few minutes, the newly formed water will drip from the tin so that you can collect it in a saucer. The water you collect in this way has actually been made during the course of the experiment. It did not exist before—it is a compound that has been produced by the union of the two elements hydrogen and oxygen. The word hydrogen means 'generator of water' and your experiment tells you how the gas got its name.

Since sugar is made from carbon dioxide and water, you are now able to name the three elements that sugar contains. **Oxygen, hydrogen, and carbon** are the three elements of which **sugar** is made—two gases and a black solid. This is a splendid illustration of the fact that a compound does not in any way resemble its constituent elements.

You have shown by your experiments that water is not really a very complicated substance: yet it is of exceptional importance to living things—both animal and vegetable.

Plentiful water is necessary not only for our crops but also for our live-stock, and a good water supply is one of the most important features of a farm that carries either beef cattle or dairy cattle. Nowadays it is becoming necessary and increasingly common to supply the stock with water from the water mains—it is piped into the cowsheds and very often into the grazing fields as well. This water, as you know, is pure and free from disease—it contains no living organisms whatever—so that it is safe for cattle to drink. Pedigree breeders, particularly, take care to use only piped water for their stock unless they have a deep well that delivers pure water.

### WHY DO FARM STOCK NEED SO MUCH WATER?

Why is an abundant supply of water so important to the lives of farm animals? Why do they need to drink so much? A horse may drink ten gallons a day or more, only to pass it all out again either as sweat or as urine. This means that a farm horse can drink the equivalent of its own weight in water every three weeks! Indeed the large quantity of water inside the bodies of most animals accounts for more than two-thirds of the animal's weight! What are the reasons for the regular movement of all this water through the bodies of living creatures?

The water that passes through the bodies of farm animals performs three important functions:

(1) The foods that the animals have digested pass into the blood-stream where they are dissolved in the abundant water that the blood contains; and the blood then carries these digested foods to the various parts of the body where they are needed. In this case the water in the animal acts as **a medium of transport.** The protein materials of which a

sheep's wool is made are, for example, carried by the sheep's blood to the wool 'roots' in the sheep's skin.

(2) Most of the water that the animal drinks enters the blood before being *excreted*, and as it passes out of the animal's body—either as sweat or as urine, or both—it carries with it the many impurities or *toxins* that are produced in the animal's blood-stream during the normal processes of living. When animals are short of water they cease to be able to get rid of all these toxins so that their 'blood becomes impure' and they lose tone. In this case the water acts as **a cleansing agent.**

(3) Some farm animals can sweat much more than others. Horses can *perspire* freely all over their bodies because their skin is covered with sweat glands and pores; but pigs sweat only at their snouts and European cattle at their muzzles; and sheep sweat very little indeed. The water that passes out of an animal's body as sweat gets rid not only of some of the toxins but of unwanted heat as well. The blood-stream temperature of any warm-blooded animal must remain fairly constant;[1] and in order to keep so, any excessive heat produced inside the body has to be quickly removed. In the case of those animals that do have pores in their skin, free perspiration

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[1] The normal blood temperatures of several animals are as follows:

(*a*) Man, 98·2° F.
(*b*) Horse, 100°–101° F.
(*c*) Cow, 101°–102° F.
(*d*) Pig, 102°–103° F.
(*e*) Sheep, 103°–104° F.

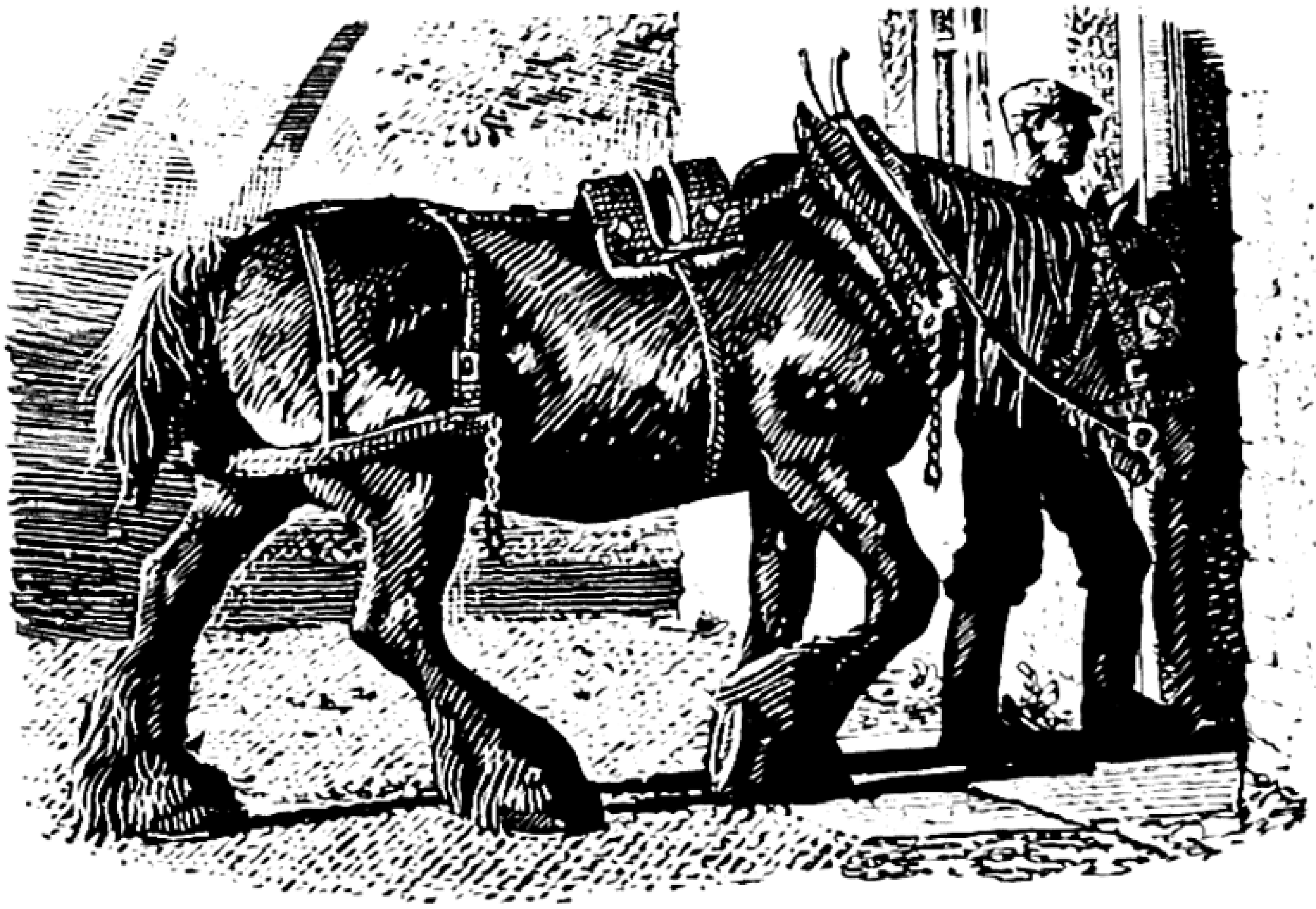
is a means of shedding a great deal of heat. In this case the water acts as **a cooling agent.** When such animals as a horse or a human being are vigorously exercised they get into a lather of sweat—especially on a hot day. How does the water in sweat carry off some of this excessive heat? The following experiment will solve the problem for you.

### THE LATENT HEAT OF EVAPORATION

*Experiment 3.* Pour a few drops of methylated spirit (or any other *volatile* liquid—petrol, for example) on to the back of your hand. You must take care to do this in a room where there is no naked flame. After a few moments the liquid will begin to disappear—and as it does so you will notice that the skin on your hand begins to feel quite cold. What has happened?

As the liquid evaporates, it carries with it a considerable amount of heat from your hand: it needs this heat in order for the evaporation to take place, and the heat absorbed in this way when liquids become *gaseous* is called the **Latent Heat of Evaporation.** It is called latent—which means hidden—because although your hand feels colder, the vapour into which the liquid turns is not made warm by the heat that is absorbed. Usually when substances absorb heat their temperature rises; but as this does not happen when evaporation takes place, the heat used up by the process is said to be hidden or latent. You used a volatile spirit for the experiment because its rapid evaporation enabled you to feel the chilling effect very quickly. But the same thing takes place whenever any liquid evaporates—

heat is taken from the surrounding materials. This, of course, is why you begin to feel cold if you stand about after getting thoroughly soaked in a rainstorm. The water evaporates from your clothing and as it does so it carries away large amounts of heat and you run the risk of a chill. Even if you keep 'on the move' the latent heat of evaporation is still removed from your clothing and body; but the movement causes you to 'burn' up more sugar in your blood, and the extra heat that is provided in this way counteracts the loss due to the wet clothes. For the same reason no farmer will allow his horses to be kept standing when, as he puts it, 'they are all of a lather' after a spell of extra hard work. He keeps them moving, gets them back to the stable as soon as possible, and gives them a good rub



Hard work on a sunny day has put old Prince 'into a lather.' Why will all this sweat chill him if he is not rubbed down at once?

down to dry them off. You may wonder why pigs, cattle, and sheep do not have more pores so that they can sweat freely. Remind yourself, however, that these animals are not nearly so active as horses or human beings; and on a very hot day it is essential, especially for pigs, to have shelter from the sunshine. Even sheep may be seen standing on the shadow side of a fence when the sunshine is excessively strong.

You should notice in passing that the loss of heat due to evaporation is another reason why heavy land keeps so cold in the spring; not only does the water that the clay contains take a long time to warm up: the soil also loses a good deal of heat as the result of the drying out of the land.

## SOURCES OF WATER FOR FARM STOCK

In bygone times the water supplies for farm animals were not always so good as they are on many farms to-day. Cattle were allowed to drink muddy pond water or slow-moving water from ditches; and there is no surer way of spreading many of the diseases of live-stock than by allowing beasts to get at water that is stagnant and muddy. Two terrible diseases of cattle—**Tuberculosis or T.B.** and **Johne's**[1] **disease**—are spread among herds by water that has been *contaminated* by infected beasts. Both these diseases are due to bacteria; and sick animals pass millions of infective germs into the open water supplies that they visit when they drink. Furthermore both diseases are so serious that no good farmer will allow infected beasts to remain on his holding: they have to be slaughtered.

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[1] **Pronounced 'Yonis.'**

The provision of clean water for stock obviously saves money 'in the long run.' Even shallow wells are dangerous sources of disease because surface drainage water and animal urine get into them easily.

The swift and shallow waters of this sparkling stream provide safe drinking for the farmer's stock. Do you know why?

Fortunately many natural water supplies are quite harmless and these can be freely used for watering stock. Rapid-flowing rivers and brooks are pure, especially in hilly districts; the clear water of such streams allows the penetration of plenty of light, and any germs that do get into them are rapidly killed by the ultra-violet rays of the sunshine. Furthermore the rapid churning and splashing of the water in fast-flowing streams causes a great deal of oxygen to dissolve in it and oxygen is a rapid killer of harmful bacteria.[1] Springs and deep wells are equally safe because the water they supply has been filtered by the deep layers of earth and rock through which it has passed. This *filtration* removes all germs and other dangerous contents.

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[1] Even so you should not yourself drink water from hill streams that sheep may have contaminated with their dung—not because of germs but because of deadly liver-fluke that spends part of its life in the body of a sheep.

No good farmer allows sickly cattle to contaminate open waters on his land—if he did, wild fowl like these mallard might carry the infection to neighbouring farms.

Many farmers even to-day have to rely on field ponds and 'pits' for watering their cattle: is any of this water safe? The suitability of pond water depends on how clear it is. Certainly a muddy pond near the farm buildings can be a 'death trap,' but if the water in field ponds is clear enough for you to see the bottom easily, then it is probably safe; mud and sediment that have been stirred up by farm stock should always be given a chance to settle again after the horses or cows have been drinking. The falling sediment carries many lurking germs to the bottom where they are killed, and the purifying sunshine that can penetrate clear waters destroys those germs that are not removed in this way. Generally, however, the farmer avoids the use of all ponds if he can. You may well think that if he keeps his own cattle free from disease, all of the ponds on his farm are bound to be free from infection. But think a moment. Is there no way in which germs can be brought from the ponds of other farms? There is. Wild water-fowl move freely from one farm to another—wild duck, moorhens, coots, and so on know no boundaries; they can and do carry infection from one holding to another. This is of no importance if the cattle do not use the waters that are visited by such birds; but it is a good reason for avoiding the use of stagnant pools whenever possible.

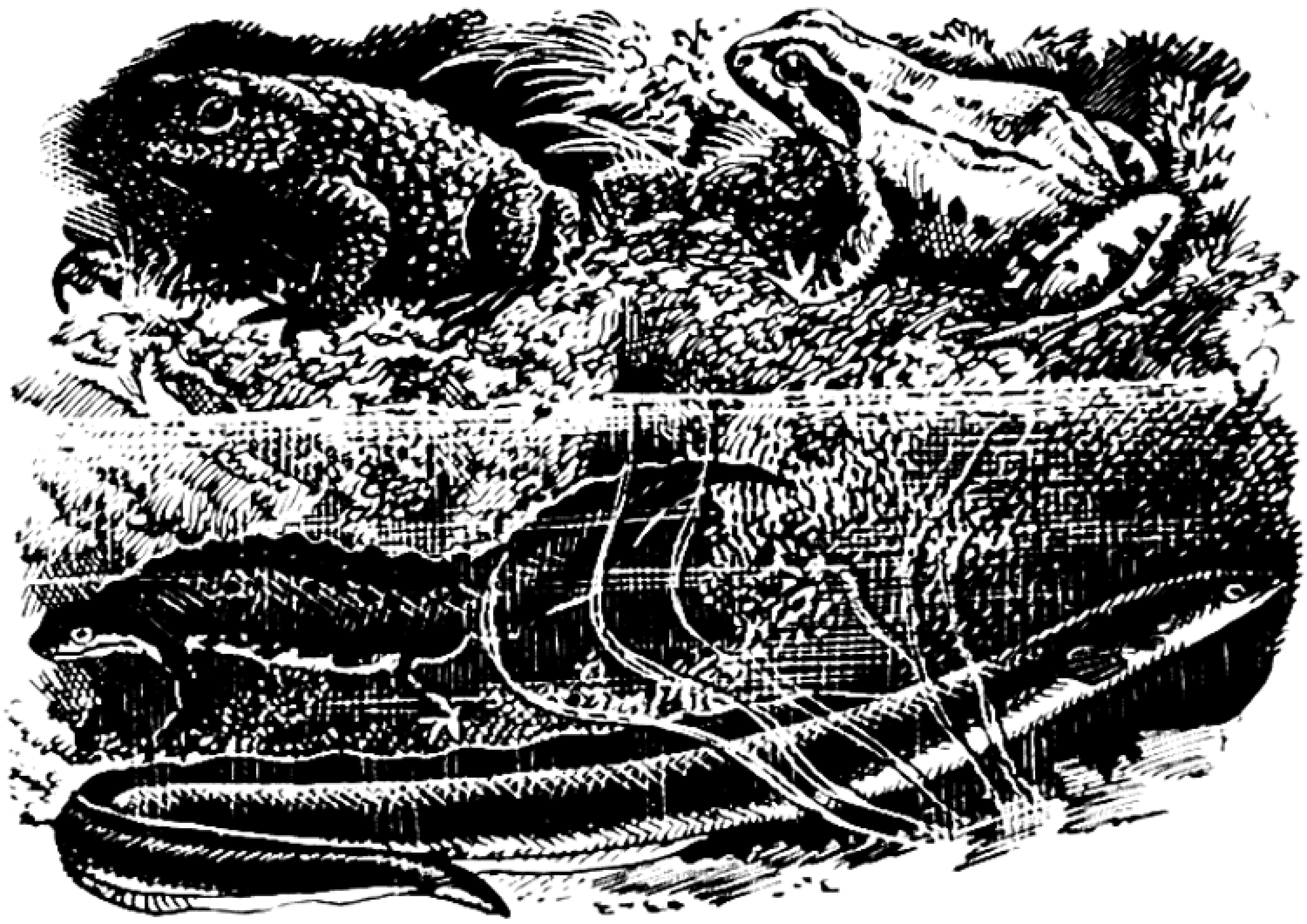
## LIFE IN INLAND WATERS

The most natural association of plant and animal life in Britain is to be found in pools and streams. Almost all the other parts of the country are covered with vegetation that is not natural to them; most of the farmland—and most of the hill country too—has been *denuded* of its natural forest trees by mankind in order to allow of farming or forestry developments. And of course that change in vegetation has had a *modifying* effect on the animal population. There are to-day no wolves or wild boars in Britain as there were in former days, and it is known that the populations of our birds and smaller land animals are different to-day from what they once were. But the life in and around many ponds and streams is as 'natural' as ever it was, and it is here that you can most easily study those natural relationships of animals and plants to which your attention was first drawn in Chapter 12 of *Rural Studies*, Book II.

If you dig out a small clay hollow, some two or three square yards in extent, and allow it to fill with water, you will be able to watch a natural association of plants and animals come into being. By the end of only one season you will find that all sorts of plants and *aquatic* insects have invaded this open-air aquarium. All our ponds are stocked by similar natural means. It is easy to see how this invasion by plants and insects can take place; plants may arrive as seeds which have been blown by the wind, or carried on the damp plumage of some bird that has been a visitor to other waters; and many water insects can fly from one sheet

The hand of man has moulded much of the face of Britain; but the surface of many a pool and pond hides a little world that has not changed 'since time began.'

of water to another quite easily. In the same way, the eggs of fish and other tiny creatures get stuck to the plumage and legs of such water birds as the mallard or the moorhen; the fish population is distributed far and wide by this means. It is interesting to notice that the natural fish population of inland waters does depend in this way on birds—without the water birds the movement of all fish (except the eel) from one pond to another would be quite impossible. The eel, although a fish, is an exception because, like the frog, the toad, and the newt, it can at certain stages of its life live either in or out of water; and although it is not a true *amphibian* it can travel overland quite easily. The life story of the eel is truly quite astonishing. All the eels that live in British fresh waters were born



The toad, the frog, and the newt can live either in or out of water: they are amphibians. Although the eel is a fish—not an amphibian—it can travel overland quite easily.

many hundreds of miles out in the deep salt waters of the Atlantic Ocean! They find their way to our shores when they are small *elvers* about three inches long, and by travelling—as they grow—up rivers, brooks, ditches, and across fields, they get to the inland waters where we find them. Nor is this the end of their strange story. When they are mature they will find their way back—across the fields, along the ditches, into the streams, and finally into the middle of the Atlantic—never to return; in the deep waters of the Atlantic they will breed and die. This is an example of the migration, not of birds but of fish. And no one knows how these creatures find their way about the waters of the world. Like bird migration, this is another of nature's great mysteries. Eels, by the way, are perfectly harmless creatures, so that there is no need for you to be troubled by them or to kill them if they take a liking to your favourite bathing pool!

### THE PRINCIPLE OF ARCHIMEDES[1]

Animals that live in water present us with a very interesting scientific problem. Why don't they fall to the bottom of the water? Most things that have weight fall to the earth if you let them drop, and a fish has weight. Why then does it not fall through the water to the bottom of the pond or stream in which it lives? If you watch a fish in an aquarium you will see that it can at times remain quite motionless, not a fin stirring, at any depth it chooses. It seems to be suspended like a bubble or a balloon in the air. By what force is it held in suspension? You could, of course, ask the same question about your own body. If you go swimming you find it much easier to keep afloat than to get to the bottom of a deep pool or the deep end of the swimming-bath. To say that the liquid supports you is not a sufficient answer, because there are some liquids in which you could not swim—you would go right to the bottom and stay there. That is true of paraffin, for example, and you should take care never to 'take a header' into an open storage tank of paraffin! That unhappy mistake was once actually made by a man living in South America; he was trying to escape from some enemies who were in hot pursuit and he plunged into a large open tank of light oil, intending to swim to the other side. That was his disastrous end; he never came up again. So you see, some liquids cannot support either your body or the body of a fish; but water can. Here then is another physical property of water that is important to life. You have now learnt something about the following properties of water:

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[1] Pronounced 'Arkimeedees.'

(1) Its unique way of expanding as it freezes,
(2) Its latent heat of evaporation,
(3) Its power of dissolving solid foods,
(4) Its ability to dissolve the gases oxygen and carbon dioxide, and
(5) Its ability to support the bodies of animals that are immersed in it.

This problem of *flotation* interested and puzzled the ancient Greeks (who were great thinkers and scholars) for many years before they hit on the solution. They wanted to know why such things as a piece of iron will readily sink in water while other things like the human body or a fish will not. The problem was even further complicated for them by the fact that some things—a piece of wood, for example—cannot be got completely under water without pushing it. The answer to the problem evaded them until one day a noted thinker named Archimedes suddenly discovered the answer. He had, so the story goes, been lying in his bath thinking about this queer state of affairs when the truth flashed upon him. He leapt excitedly from the water shouting: 'Eureka! Eureka!' which in the Greek tongue of that day meant: 'I've found it! I've found it!' It is said that he was so overcome by his discovery that he forgot to replace his garments before appearing in public; but the truth about that is not clear.

His discovery, however, was clear enough. When any object is immersed in water it receives an upward pressure from the water—*and the force of that upward pressure is equal to the weight of the water that the immersed body displaces.* That doesn't sound very illuminating until you begin to think about it.

When we say that iron is heavier than aluminium we don't really mean exactly what we say. A piece of iron as big as a match-box would obviously be lighter than a piece of aluminium as big as a house. What we really mean when we say that iron is heavier than aluminium is that *volume for volume* the iron is heavier. Really what we should say is that the iron has a greater *density*—it has more weight *in an equal volume.* Now let us think again about the principle of Archimedes. If iron had the same density as water then a cubic foot, say, of each would weigh the same; and when the iron was fully immersed in the water the cubic foot of water thereby displaced would press the iron upwards with a force equal to its own weight—i.e. equal to the weight of the iron. The iron would float because its weight had been balanced by the upward thrust. Because iron does not float in water we know that it must be denser than water. And indeed it is—it is more than five times as dense. The human body, however, and the body of a fish have nearly the same density as water so that when they are immersed *they lose their weight* almost entirely because of the equal upthrust of displaced water. Now you will be able to understand why it is impossible for paraffin to keep you afloat: the weight of paraffin is, volume for volume, less than the weight of the animal body. For this reason, even when you are fully immersed,

Why does this swimming polar bear find it difficult to sink in water?

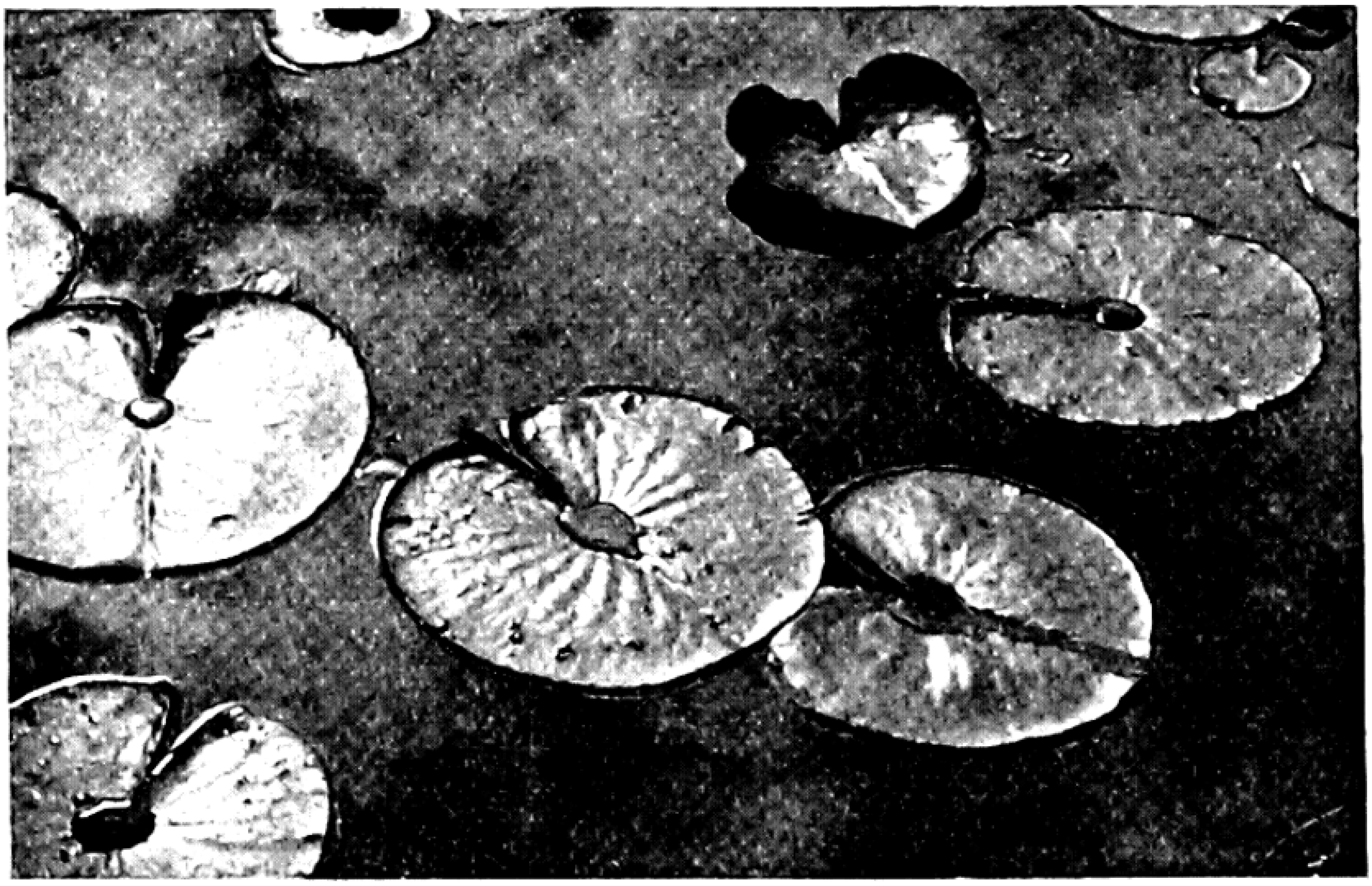
you do not displace enough paraffin to equal your own weight and, the upthrust of the paraffin being less than your weight, you fall to the bottom.

A consideration of the principle of Archimedes makes us realize this remarkable fact: *the density of the bodies of all water creatures must be about equal to the density of water.* If it were not so they could not live in water at all: they would not be able to move up and down in it—or to remain suspended like the fish in the aquarium. You have learnt in other books of this series how to watch birds and moths at close quarters. Let us now consider the ways and means of watching the behaviour of aquatic animals—fish, amphibians, aquatic insects, and so on.

## THE AQUARIUM

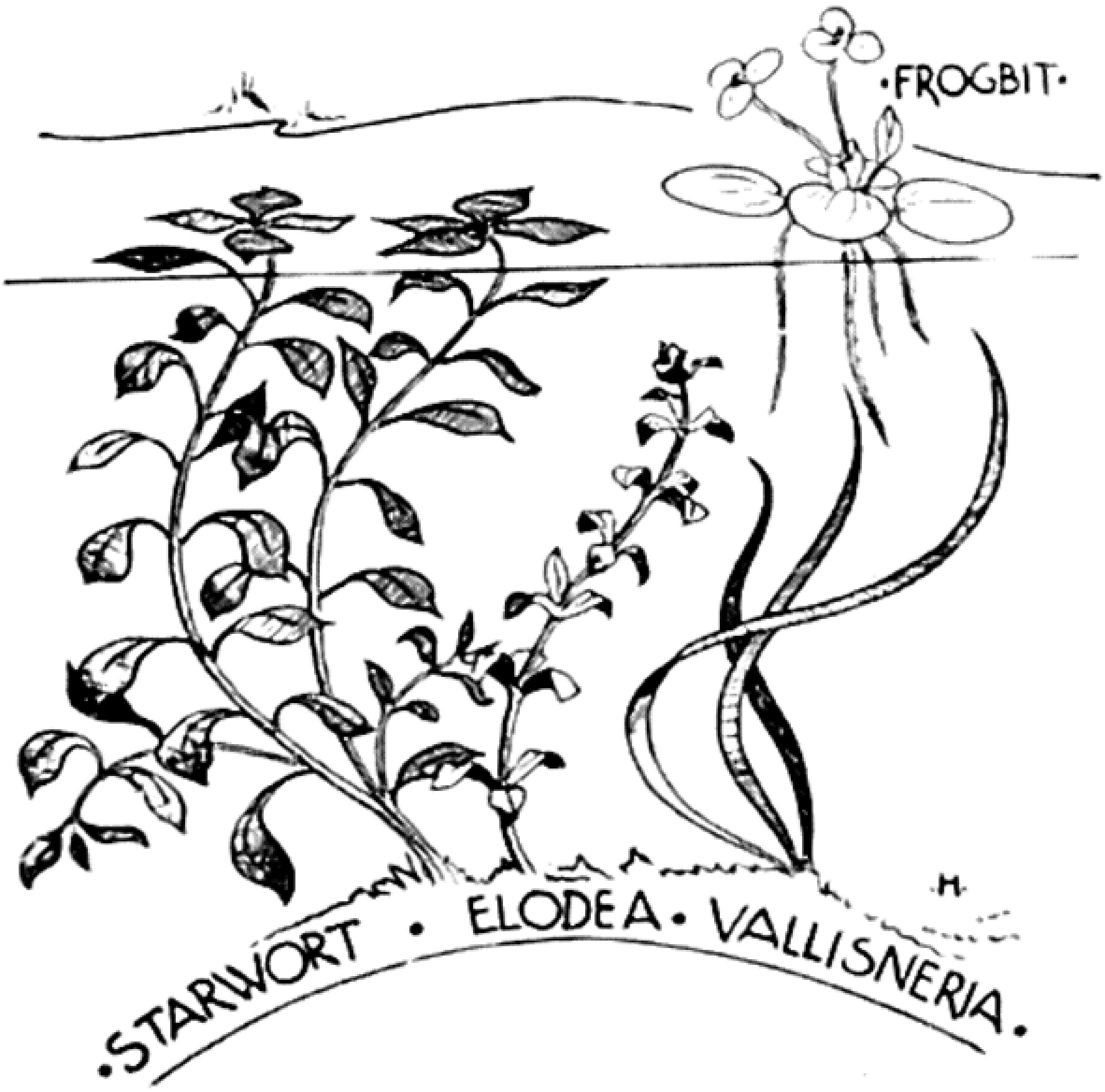
It is necessary at the outset to stress the importance of providing suitable quarters for living things if we are to take them out of their natural surroundings where they enjoy a full and lively existence. In setting up an aquarium it is necessary to copy those natural surroundings as closely as possible, otherwise our captives will undoubtedly suffer; they will be no pleasure to you and they may well die.

You learnt from your experiments in Book II (Chapter 12) that water creatures and water plants live together in a natural partnership, each providing the other's needs in a number of ways: by the process of respiration water animals (including many insects of course) provide water plants with the carbon dioxide that is necessary for photosynthesis; and water plants provide water animals with the oxygen that they need for respiration. The plants produce this oxygen as a *by-product* of photosynthesis. Any flourishing pond contains both water plants and water animals, and you must make sure to copy this partnership in any aquarium you establish. Furthermore there is always plenty of shade to be had in natural water—the pond or stream may be fully exposed to the sun, but there are plenty of under-water caves and crevices to which the inhabitants can retire if they need to. For this reason you must ensure adequate shade for the living things in your tank. There will need to be some light of course for photosynthesis to proceed; but the direct rays of the sun playing on a small tank of water would be too strong for the animals in it and you must provide suitable shelter for them by growing plenty of



Here you see the leaves of our native water-lily. In what two ways are they of assistance to the fish that live beneath them?

water plants and by placing the tank in a north-facing window. It is a good idea also to cover three sides of the tank with a dark distemper—either green or grey. You will need a rectangular tank with flat sides.



Let your aquarium plants get well established before introducing the animals.

Circular tanks are quite unsuitable, as the water in them acts like a lens and distorts the appearance of the occupants so that you never get a side view of them as they really are. The tank should be at least a foot or more in length, about nine inches to a foot in depth, and the same in width.

For your collecting you should select a pond that has plenty of plants growing in it—not only plants whose leaves float on the surface but also those that grow entirely beneath the surface; fully submerged plants are the most effective source of oxygen for the animals.

Among the commonest water plants are starwort (*Callitriche*) and Canadian pond weed (*Elodea*). Water milfoil—a name which means *the plant with the thousand leaves*—may also be one of your finds. All three of these have plenty of under-water leaves and they are very suitable for your purpose. Another common pond plant that you may find is water crowfoot, which has small attractive white flowers with five petals. This plant belongs to the buttercup family, and it has the quite unusual habit of bearing two different kinds of leaf that are not even remotely similar; the surface or floating leaf is somewhat round in shape and it is all in one piece, but the under-water leaves are split into large numbers of thin threads. Whatever species of plant you find you will need a dozen or so good specimens, complete with roots, for the size of tank mentioned. A larger tank will, of course, need more. If you can find only one kind then you need a dozen plants or so of that—they will oxygenate the water quite satisfactorily, but the tank will not be quite so picturesque.

The submerged leaves of the water crowfoot are thread-like, but the floating leaves are flat.

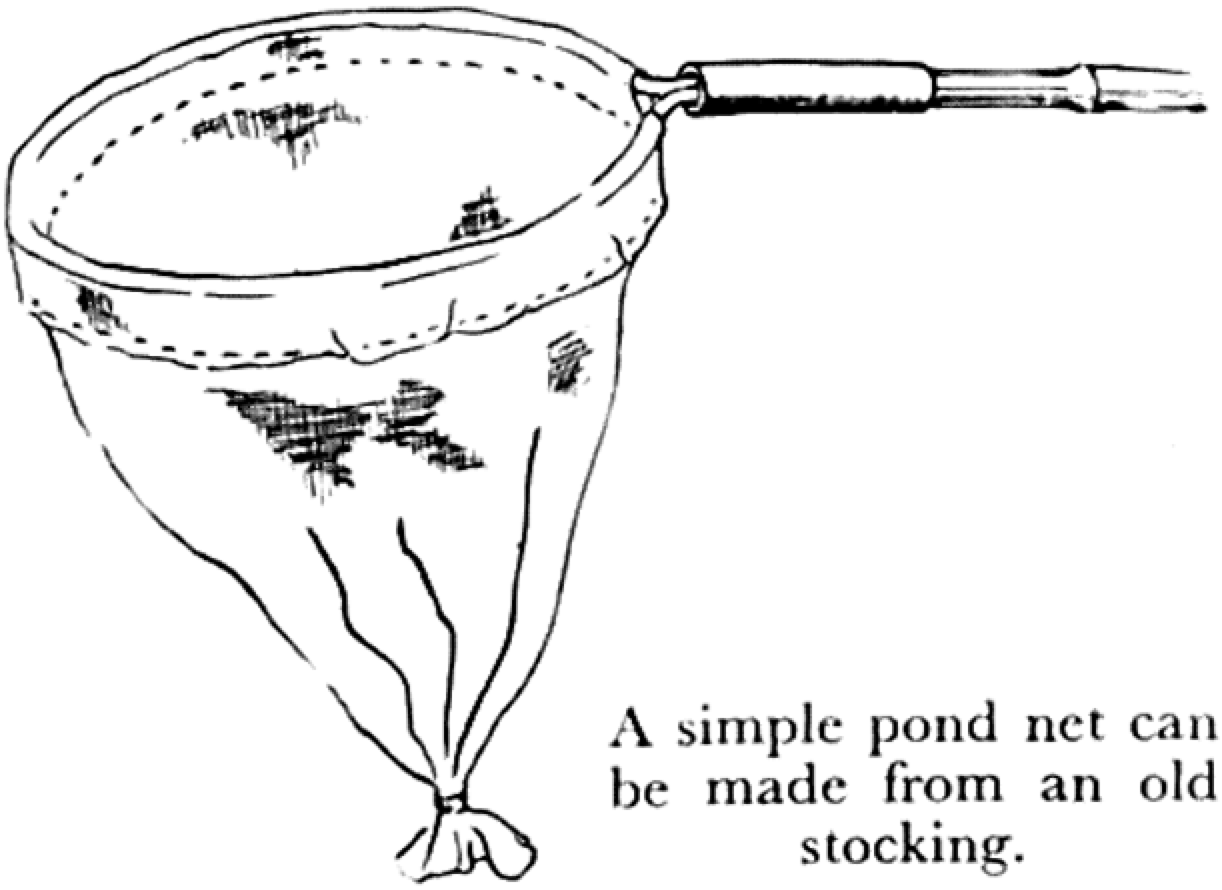
Cover the bottom of the tank with about two inches of *clean* sand and then carefully set your plants. You must do the planting as thoroughly as you do when working in the garden—anchor the roots firmly into their new home. They will look a sorry mess at this stage, but they will pick up again when they begin to grow, provided you kept them thoroughly damp on the way home. In order to provide a sheltering place for small fish, place a large hollowed-out stone on the sand. This stone should be about the size of a large jam-jar and should be quite hollow on one side. Fish that like occasional concealment will appreciate this shelter. Furthermore, if you wish to keep one or two newts, they will need to be able to get out of the water on to 'dry land' from time to time. In order to make this possible, the shelter stone for the fish should be big

The graceful plants and lively animals of this water world are healthy and vigorous because the aquarium was carefully planned.

enough to rise above the surface of the water; and one side of it should be sloping so that whenever these amphibious animals wish to leave the water they can climb easily on to the airy platform. Ideally, the upper portion of this stone should be hollowed so as to provide a nook in which your newts can hide, as they are fond of privacy sometimes. When the sand, plants, and shelter stone are all in position, the tank can be filled with water. Rain water or non-chlorinated tap water will do quite well.

Filling the tank presents a problem, because the rapid flow of water from a jug or a watering-can may easily disturb the sand and uproot the plants. A good way of preventing this disturbance is to lay a sheet of newspaper over the sand and plants before attempting to add the water. As the tank fills, the paper rises upwards and the plants remain securely anchored in the sand. Fill the tank to within an inch of the top and then, in order to give the plants a good start, place it in a *sunny* window for a fortnight. If a green growth of minute green plants starts on the glass remove them from one side of the tank so as to keep a clear window for looking through, but leave them on the other sides as they are valuable food for many tiny creatures. At the end of a fortnight the plants will have become well established, and you will see that they have started into active growth again after the shock of their removal. When this happens you can go in search of the animal inmates.

A net that will serve to catch small fish and most kinds of insect can easily be made from a long stick, a piece of thick wire, and a piece of old nylon or silk stocking—even an old sock will do! The smaller creatures, however—water fleas and such like—can be caught by using a jar as described in *Rural Studies*, Book II, Chapter 12. There is, of course, a closely linked food chain in operation among the living things to be found in water—from the most microscopic plants and animals at one end of the chain to the largest fish, such as pike, at the other end; and it is desirable for your tank to contain animals of different sizes for this reason.[1]



A simple pond net can be made from an old stocking.

The best fish to begin with are sticklebacks, minnows, and small gudgeon. A few expeditions with your net and a large jar should provide you with all you want of these.[2] Remember, however, that a small tank will carry only a few fish. You may reckon one inch of fish to each gallon of water, so that a tank

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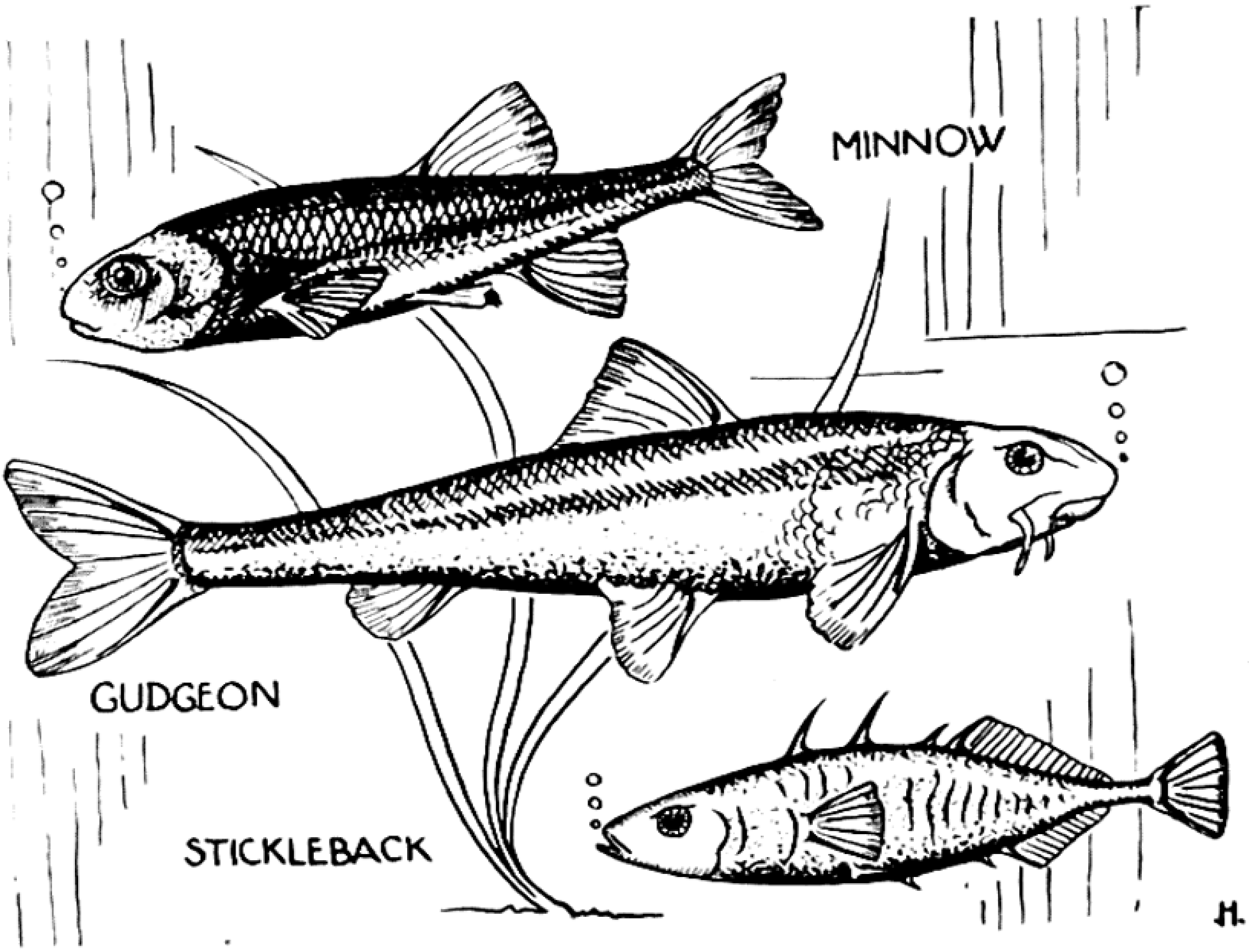
[1] When collected, the tiniest creatures—fleas and so on—should be kept in a bucket. The water fleas will thrive in abundance if you feed them on brewer's yeast. Take a dessertspoonful of yeast and make it into a thin, smooth cream with water; this is enough for a week, and it should be given, a half each time, on two separate occasions.

[2] If you are unable to capture your own fish, suitable specimens can be bought from the Biological Supply Agency, Rhydyfelin, Aberystwith.

12 inches by 9 inches by 9 inches—which holds about three gallons [1]—can contain only 3 inches of fish, i.e. one 3-inch fish, two 1½-inch fish, or three 1-inch fish; no more. Sticklebacks, which are especially lively during the breeding period in spring, can often be got from ponds; but you are more likely to get minnows and gudgeon from a small river, though you may be lucky with a pond catch. You will soon become expert with the net which should be dipped frequently as you walk round the pond. Do not wait until you can see your quarry—some of the best catches are made by chance dippings.



British freshwater fish are much more interesting to watch than goldfish. These three are quite suitable for captivity because they remain small throughout their lives.

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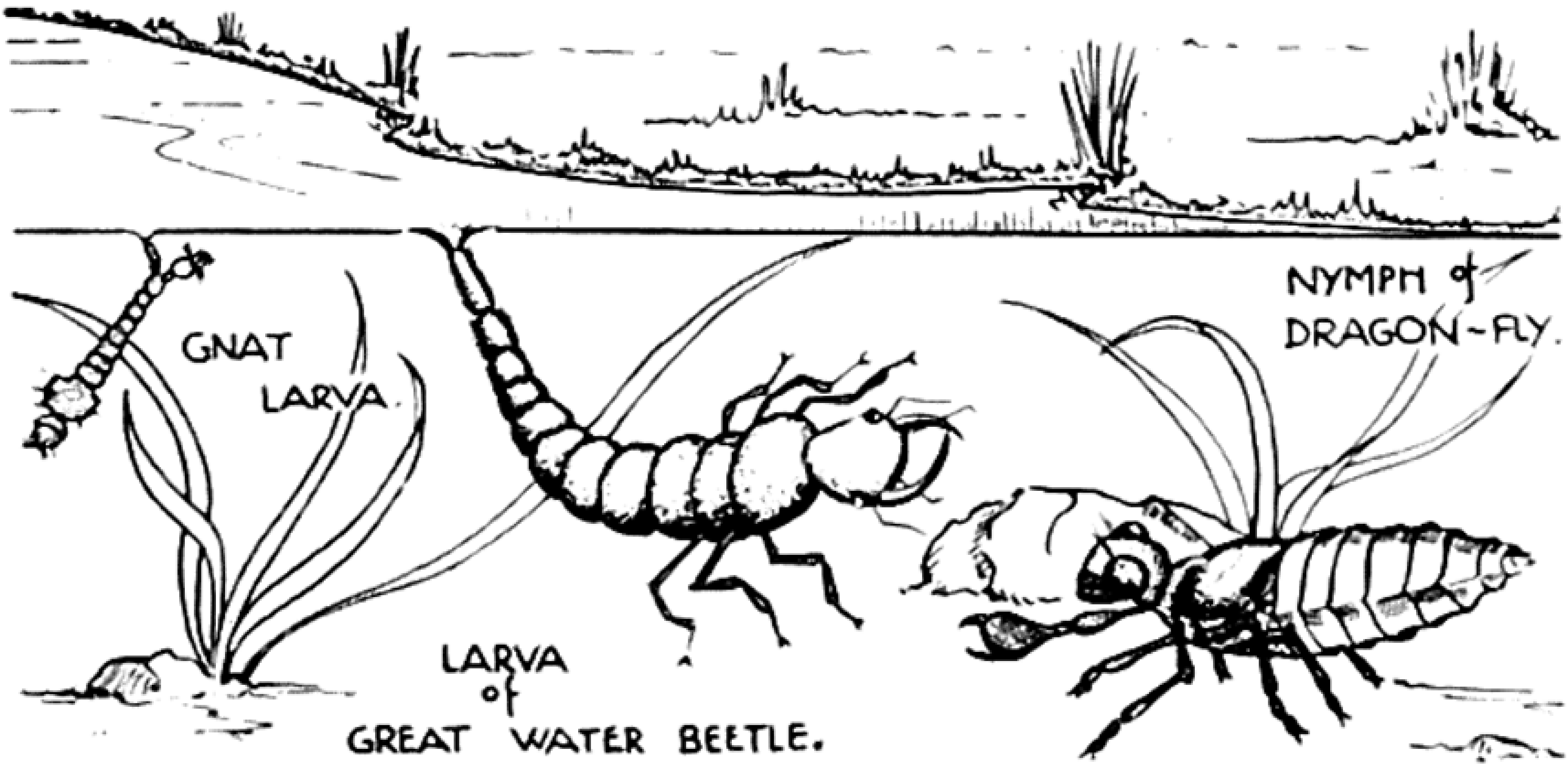
[1] In order to convert cubic feet to gallons, multiply by 6¼.

The insects you are likely to find most easily are the water beetles and their larvae, the dragon-fly larvae, caddis-fly larvae, and the larvae of mayflies and gnats. There are scores of other creatures, of course, and in order to identify and name your catches you will need a good handbook on pond life.[1] You should not keep the bigger carnivorous insects in the main tank for very long; if you do you will find even your fish being attacked! The worst offenders are the dragon-fly larvae (or nymphs) and the larvae of the large carnivorous water beetles called *Dytiscus*; two or three of each of these will be enough for you to watch.


GNAT LARVA.
LARVA of GREAT WATER BEETLE.
NYMPH of DRAGON-FLY.

If there are any fish in your tank, the gnat larvae may not last very long!—but keep a careful eye on the other two: they may attack even your fish.

Newts too are *predacious* animals, but if you provide them with worms they will rarely interfere with the other inhabitants of the tank. If any of your flesh-eaters do become too voracious they should be removed to private quarters in a second tank. Do not, however, forget to feed them, and when you no longer want them they should be returned to the pond. Remember your obligation either to look after your captures or to return them to their natural surroundings. Feed the fish with live water fleas (*Daphnia*) if you can get them. There should always be a good supply of live fleas and other tiny 'fry' for them in the tank, but if you are in any doubt about their food supply, you can put in a daily *sprinkling* of dried *Daphnia* or an occasional worm (those blood-worms that can be got out of a heap of *old* manure are best) or some tiny pieces of chopped, uncooked meat, together with daily sprinkling of a few minute pellets of *brown-bread* paste.[1]

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[1] One of the best is *Freshwater Life of the British Isles*, by John Clegg, published by Frederick Warne & Co. in the Wayside and Woodland Series. (Price 21*s*.)

## SURFACE TENSION

A number of insects spend their lives on the surface of still water, the whirligig beetles and the pond skaters being among the commonest. It is unwise to try to keep these in captivity, because there is not enough room for them on the surface of an aquarium, and they will probably make their escape, only to perish in the room where your aquarium is kept. Their ability to exist on the surface of water is, however, very interesting and worthy of note. The surface film of water (and of all other liquids) behaves rather like a stretched skin so that it is difficult for light objects, including insects, to penetrate it. When we speak of the *surface tension* of water we are referring to this surprising *phenomenon*. Not only can pond skaters, whirligigs, and so on move about on top of this 'skin'—insects that live beneath the surface can attach themselves to it from underneath and hang head downwards in the water. Gnat larvae do this when they are breathing air (their breathing parts are at their tail ends), and you will undoubtedly see them behaving in this way if you keep one or two of them in captivity.

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[1] When giving dead food material you should supply no more than the creatures can thoroughly clean up each day. Otherwise the tank will become foul.

If you build your aquarium carefully and give it daily attention it will provide you with continuous pleasure during all the months of spring, summer, and early autumn. When the year begins to draw to a close, however, the time has come to take its inmates back to their proper home in the pond. Many of them will *hibernate* by nature and they need this annual rest.

## THINGS TO DO

(1) Write a composition entitled 'If the properties of water were to change . . .' You should consider each property of water in turn and think of the effects that a change of that property would have both on the lives of living things and also on farm work in the fields.

(2) Answer the following questions:
  (*a*) What is a chemical compound?
  (*b*) What is a chemical element?
  (*c*) Of what elements is water a compound?
  (*d*) Of what elements is sugar a compound?
  (*e*) What fraction approximately of the weight of a mammal is due to the water the animal contains?
  (*f*) What happens to your food *after digestion*?
  (*g*) What is the latent heat of evaporation?
  (*h*) Which kinds of water supply are likely to be dangerous to farm stock? Give reasons.
  (*i*) Which kinds of water supply are likely to be safe for farm stock? Give reasons.
  (*j*) Water plants that live in association with water

animals supply those animals with an important need and vice versa. Explain how water plants and water animals help one another in this way.

(*k*) What quantity of fish could you keep in an aquarium that measured 2 feet by 1 foot by 1 foot?

(*l*) What must you have in your aquarium if you keep amphibians?

(*m*) How much approximately do you weigh when you are swimming under water?

(3) Find out from the farmer how much water his horses drink:

(*a*) On a working day in winter.
(*b*) On a working day in summer.
(*c*) On a day of rest in winter.
(*d*) On a day of rest in summer.

Write down what he tells you in your Country Book and give explanations for the variations.

(4) Ask the farmer how much water is drunk in winter by

(*a*) His bull.
(*b*) His calves.
(*c*) His dry cows and heifers.
(*d*) His dairy cows.
(*e*) His fattening bullocks if he keeps any.

Write down the answers in your Country Book and explain the differences.

(5) In *Rural Studies*, Book III, Chapter 8, you were shown how to make a study of the plants and animals on a chosen area of land. Select a pond or part of a pool, or a stream, and make a similar study. Let the study be as thorough and as neat as the one you did last year. Your drawings will need to show not only the plan of the pond but also an *elevation* (sideways view) that indicates the plants growing at various depths. In your final chapter you should try to explain how the various plants and animals came to be where they are and the ways in which they contribute to one another's lives.

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